

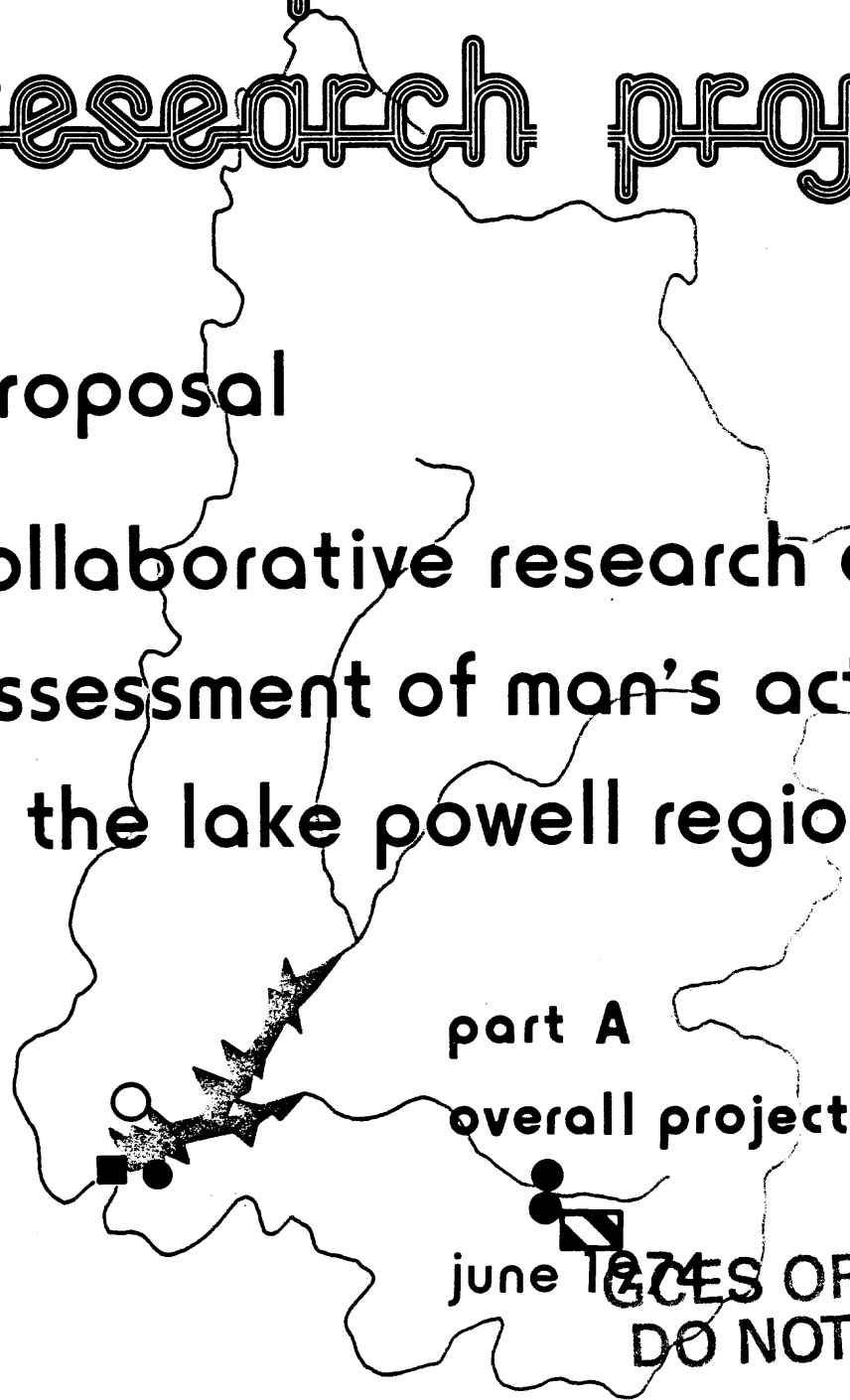
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lake powell research project

proposal
collaborative research on
assessment of man's activities
in the lake powell region



part A
overall project proposal

june 1974
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Part A -- The Overall Project Proposal
of
One PROPOSAL Submitted to

NATIONAL SCIENCE FOUNDATION
RESEARCH APPLIED TO NATIONAL NEEDS (RANN)

entitled

COLLABORATIVE RESEARCH ON ASSESSMENT OF MAN'S
ACTIVITIES IN THE LAKE POWELL REGION

with

Budget Requests from Nine Participating Institutions

Arizona State University

Dartmouth College

John Muir Institute
for Environmental Studies, Inc.

Northern Arizona Society of
Science and Art, Inc.

University of Arizona

University of California, Los Angeles

University of California, Santa Barbara

University of New Mexico

University of Rochester

Duration: June 1, 1974 to May 30, 1976

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I. GENERAL PROBLEM, CONCEPTUAL FRAMEWORK, AND THEMES OF THE PROJECT

A. Statement of the General Problem

There is a need for wise management of natural resources in the nation, particularly in developing areas. The general societal problem which prompts the proposed research is how to mediate between competing interests in the development of natural resources in the Lake Powell region.

The Lake Powell Research Project (LPRP) has concentrated its efforts during the 1972-1974 funding period on problems inherent in the development of the water resources of the Upper Colorado River Basin (UCRB), especially in the Lake Powell region. Until recent years, water was the dominant concern of regional planners in the Upper Basin states. Decisions leading to the impoundment of Upper Basin waters assumed that regional development would proceed from increased water use for irrigated agriculture, growth of urban areas, and expansion of the secondary tourist industry at Lake Powell and other Upper Basin reservoirs. Prior to the 1960's production of electrical energy through coal-fired powerplants was not considered as implying major demands on the Upper Basin water supply. A number of recent developments have changed the situation radically:

(1) The so-called "energy crisis" in the nation is leading to the exploitation of coal reserves near the Colorado River on a scale which creates competing demands for water.

(2) The growth of concern nationally for protection of the environment has introduced regulatory mechanisms which may substantially change the whole process of resource development.

(3) Changing expectations and perceptions of benefits to be derived from resource development which are held by regional rural Anglo and Indian populations are introducing new political factors into the decision-making process.

(4) The needs of the tourist-recreation industry have grown stronger and conflict with those of the energy industry as a result of the public's conflicting demands for energy and recreation.

(5) Continuing population growth and urbanization in adjacent areas have increased the need for rapid

development of electrical energy sources and have created conflicts with environmental, recreational, and agricultural demands.

There is, therefore, a need for research to analyze and describe the changing patterns of competition for natural resources in the Lake Powell region and to identify, in as much detail as possible, the nature of the "tradeoffs" which are inherent in the adoption of alternate management policies.

B. Conceptual Framework

1. The Dynamics of Change in the Lake Powell Region. Lake Powell is one of the most important elements in the ambitious Colorado River Storage Project (CRSP) authorized by Congress in 1956 and spanning decades of construction.

The projection of interests and expectations over the period of years necessary for completion of CRSP necessarily implied certain assumptions of stability and lack of change in the social and natural systems of the region. For example, at the time of CRSP authorization and construction of Glen Canyon Dam, there existed certain expectations about the future quantity and quality of water available in the Colorado River Basin. Further, the creation of Lake Powell, the largest impoundment and the "cash register" of CRSP, was intended to perpetuate an established pattern allocating benefits among various interests in the region. Certain participants planned to achieve particular goals directly through the creation of the lake. Other interests received indirect benefits and believed that other projects would follow construction of Glen Canyon Dam which would serve their aims.

The past decade, since the filling of Lake Powell began in 1963, has been a period characterized by striking changes in the natural and social systems of the region and their interactions. Some of these changes may be identified as national in origin, some are regional, and others may be related to the construction and management of CRSP itself.

The introduction of a large artificial lake into a developing, sparsely populated area prompted complex

changes in the ecosystem with biological, physical, and chemical consequences, some of which are perceived as economically and/or aesthetically significant by elements of the social system. The construction of the dam and the resulting lake caused an influx of permanent and transient populations with increasing claims and demands. Because some of the initial benefits expected were mutually inconsistent or infeasible, not all of the interests which hoped to be served had their expectations fulfilled.

A few examples may be cited. Conservationists have witnessed the entry of Lake Powell into the Rainbow Bridge National Monument. Rural areas of Wyoming, Utah, and Colorado have seen hoped-for irrigation projects go without funding. Navajos have become impatient with the retarded development of the Navajo Indian Irrigation Project (NIIP).

New national goals and objectives have also introduced change. In the late 1960's and early 1970's, environmental quality became an important national concern. In place of the various small conservation groups which were once excluded from the process of allocating resources, a large national environmental movement emerged to assert that environmental impacts must be accounted for in decision-making. Disadvantaged groups, including American Indians, which have in the past received very little benefit from developments, have begun to claim greater equity.

Concomitant with the increased significance of these new interests has been the emergence of the national "energy crisis." The identification of the Lake Powell area as a desirable location for extensive energy production and coal extraction has significant implications for change in the present natural and social setting. The need to supply both regional and national demands for energy, coupled with the available rich coal reserves in the vicinity of Lake Powell, has resulted in new demands on water resources. Some of these new claims directly contradict those of the traditional participants in the allocation of water resources.

We expect that such dynamics of change will continue to alter the physical and biological environment, and will generate new demands and expectations as well as frustrate the expectations of established interests.

Having recognized the dominant role of change in the Lake Powell region and the societal need for predicting and influencing the course of that change, we recognize the organizing concept of the LPRP in the 1974-1976 funding period to be the impact of change upon various natural and social subsystems. The Project intends to focus on the ramifications of certain trends and changes which are most salient to national and regional societal problems.

The interdisciplinary approach adopted by the LPRP at the outset is especially appropriate to identify and analyze the synergistic effects of change, when an alteration in social or political relations, for instance, may eventually profoundly impact natural systems. Investigations from diverse academic disciplines are able to assess the total force and impact of change through cooperation in data gathering and interdisciplinary analysis of change. A number of foci for analysis have been chosen on the basis of the salience of the problems involved and their utility in illuminating change.

The following major subjects are themes chosen by the Project: regional development and national priorities; changing processes of institutional decision-making; changing patterns of urban-rural relationships; the impending gap between water supply and demand in the Upper Colorado Basin; the lake ecosystem in transition; and alternative futures for energy production in the region.

These general areas of research interest have led to the formulation of more specific research hypotheses which provide the basis for the individual research proposals. Exhaustive examination of each area of concern is beyond the capabilities and resources of the LPRP in its present form. Consequently, specific limited research topics have been defined to focus on problems which appear to be representative of regional processes. Individual subprojects have formulated their proposals to elucidate in detail the methods of investigation they will undertake to fulfill their role in the common endeavor. Topics of the Project are found on pages A-5 to A-14. Subprojects are found on pages A-15 to A-52.

2. Societal Problems Chosen as Project Themes

a. Regional Development and National Priorities. National economic policies for regional development have been based on the assumption that although the profit derived from the development of resources by public investment and private capital may flow to private interests outside of the region and although the developed resources may be consumed in large part outside the region, the people of the region will receive economic benefits. According to the assumption these benefits will lead to the modernization of local economic, governmental, and social institutions, and the region will achieve social and economic parity within the nation. This assumption has frequently been used as a justification for Federal subsidization and support of development programs such as irrigation and hydropower projects.

Research findings by LPRP in Year 1 indicate that this assumption may be ill-founded in the case of the Navajo. Anticipated confirmation of these findings raises questions concerning the reasons for this developmental failure. Two distinct possibilities must be explored:

(i) It is possible that the reservation status of the Navajo places them in an anomalous legal and political position vis-a-vis the region. The peculiar institutional arrangements of an Indian reservation may preclude the flow of economic benefits back to tribal institutions, while such barriers do not exist to impede flow of benefits back to local institutions in counties and states. Should this be the case, comparable investigations of the non-Indian populations of the area should reveal that economic benefits are, in fact, being experienced by residents of the region. Local governmental, economic, and social institutions should show increasing parity within the nation. Remedies to the situation would then be sought in the area of Federal Indian policy.

(ii) It is also possible, however, that regional interests are always at a disadvantage when negotiating with large corporate conglomerates that are both more sophisticated and more knowledgeable. The conglomerates present a unified front to the less well-organized representatives of the region who are most frequently politicians, and they most frequently owe their allegiances to business interests and not local populations. The economic structures of relatively isolated regions are

generally dependent upon external sources of goods and services, for it is difficult to generate the needed capital and to justify the local production of these items. Consequently, the economic benefits derived locally from resource development are rapidly expended purchasing the basic materials and services not produced locally.

(iii) It is also possible that under-employed local populations may opt for immediate benefits. They may prefer to increase current consumption rather than utilize benefits to finance capital formation and local production. Complicating the issue further in southern Utah is the fact that coal reserves are on Federally rather than locally controlled lands.

If capital-poor regions tend to be at a disadvantage, we would expect many of the Navajo findings to be replicated by the investigation of local non-Indian populations. Information obtained from the local Whites will indicate if they have opted for immediate benefits to the exclusion of capital accumulation. Furthermore, we would expect this regional disadvantage to be increased if planning procedures and regulatory mechanisms are held in abeyance during periods when there is a nation-wide shortage of a resource. To explore these ideas further we are proposing a sociological study of the Anglo population of the region, as well as a comprehensive study of energy development in the Kaiparowits Plateau area, to examine the conflicts between national and regional requirements.

b. Changing Processes of Institutional Decision-Making. Significant changes appear to be occurring in the decision-making processes related to water and energy resource allocation in the UCRB. In the past, water management decision-making processes have dominated natural resource planning and development in the UCRB. Presently, however, it appears that concurrent pressures for environmental protection and energy production are necessitating the use of different decision-making processes.

Historically, water has been allocated among the states of the Upper Basin through a coalition of local, state, and Federal institutions. Ruinous competition has been thus avoided by a common awareness that the regional utilization of water requires massive Federal

investment and subsidy obtainable only through the efforts of a united political front. The major decisions allocating benefits have been made or substantially influenced by the beneficiaries themselves, with minimal consideration of external costs and interests. Recent river salinity control proposals reflect this traditional mode of decision-making.

This traditional mode of decision-making is being severely challenged by an alternative mode that involves conflict and negotiations among competing interests which do not share a common set of values. These interests fight battles in the courts, in legislative halls, and in administrative agency public hearings. Conflict resolution is achieved by the application of general rules rather than through a finely turned agreement among participants sharing a common interest. Proposals for application of water quality standards to the water of the Colorado River, conflicts over energy developments and consequent degradation of air quality, and battles over the sanctity of national parks and monuments all suggest this regulative framework of decision-making.

Similarly, the mode of energy decision-making is undergoing change. Previously, the central participants in energy development decision-making were the energy-producing industries themselves. Even governmental entities only peripherally had access to the capabilities, time, information, and alternatives which made it possible to influence the context and content of decisions.

With the emergence of both the "energy crises" and the "environmental crisis," come demands for "regulatory" types of decision-making mechanisms. Thus, the use of courts and regulatory (as opposed to "program") agencies has increased.

A variety of changes in procedural requirements have resulted from this increasing reliance on regulatory decision-making, including new principles and standards for evaluating projects that incorporate environmental costs and benefits in the economic analysis; new administrative regulations affecting public participation; and the environmental impact statement requirements of the National Environmental Policy Act of 1969. All of these developments have been designed to provide public access

to, and influence in, the decision-making processes within agencies.

Changes in decision-making processes can be expected to be uneven and incremental. Political science studies will indicate the circumstances under which decisions will be made in the traditional manner with mutual accommodation among participants and will indicate when regulative mechanisms will be employed. The critical factors related to innovation in decision-making processes will also be identified. Program agencies are being subjected to contradictory demands to maintain relationships with established constituencies and, concurrently, to develop channels of communication with new participants. How these agencies respond will affect their future roles in policy-making in the Lake Powell region.

c. Changing Patterns of Urban-Rural Relationships. An area of primary concern to the LPRP is the relationship of urban metropolitan centers to relatively isolated rural areas. The significance for a democracy of the independent yeoman farmer has been an insistent theme in American social and political thought since at least the time of Jefferson. The autonomy of local areas has declined rapidly, however, with the growth of industry, the mechanization of farming, the attraction of rural migrants to urban centers, and the growth of a mass society. The penetration of the lives of rural dwellers by outside forces is manifested in myriad ways: the growth of agribusiness; statewide control of school curricula; the availability of mass communications; the growth of highways; regional planning of health facilities; and the control of local industries and businesses either directly or indirectly by nationally based corporations. For these and other reasons, most segments of local societies appear increasingly to want economic development of their areas. Such development brings with it jobs, so that youth, it is hoped, will no longer migrate, and the general standard of living will improve. It also brings changes that may come to be regarded as dysfunctional or undesirable: influx of newcomers may disrupt the settled stratification system of the community, and there may be despoilation of the land. This has happened in the Appalachians. Indeed, the price of development may be the shattering of whatever fragile autonomy--or illusions of autonomy--rural areas have been able to retain.

Decisions concerning the development of natural resources may please local residents for the reasons suggested above. It is problematic, however, whether they have had any voice in those decisions. It is also uncertain whether the benefits accruing to these populations meet their expectations and whether they are evaluated by the locals as being worth the costs.

The Anthropology, Sociology, Economics, and Epidemiology Subprojects are to varying degrees concerned with assessing the impact of industrial and other developments on local communities. Changes in fertility patterns, household organization and income, social structure, and personal values may be expected as a result of economic development. Whether the changes which do occur are desired by the people themselves or whether the costs outweigh the benefits are clearly factors that need to be considered by those concerned with the impact of metropolitan demands on rural satellite communities.

d. The Impending Gap between Water Supply and Demand in the Upper Colorado Basin. The future distribution and allocation of water in the Colorado River Basin to all its claimants is a zero-sum game in which the potential demand greatly exceeds the supply. At the present time, allotments to Basin states are filled by current and committed uses. The exceptions are Utah and Wyoming, where a relatively small residue is thought to be available for possible future use.

There is reason to believe that the system may already be oversubscribed by allotments claimed by the states and Indian water right claims. Present allocations of water were made on the basis of overly optimistic projections of annual river flow, which in turn were based on data gathered during an abnormally wet cycle. Whether claims to Upper Basin water exceed the supply as thus calculated will become evident when most of the committed water is put to use.

Whatever may be the relationship between supply and demand today, there can be no doubt that a gap is imminent due to potential claims arising from projected growth in agriculture, growth in electric power production, increased exports to metropolitan areas outside the Basin, and increased demands for improved water

quality. It is estimated, for example, that extensive exploitation of coal in the Kaiparowits region for power production will require more water than is available from Utah's uncommitted allocation.

Four basic strategies could be combined to close this gap. They are (1) rationing and reuse, (2) transfer between types of water use, (3) remedial salinity projects, and (4) augmentation to the Basin surface water supply. Implementing each of these strategies requires both refined information on the actual supply and water available for consumptive use and the ability to predict what the water supply will be insofar as is possible. Scientific methods now exist to enable the LPRP to reach more realistic estimates of future supply than those currently in use.

In addition, insofar as a given strategy may require impoundments and diversions of water, the resultant losses to the river system must be quantitatively understood. These losses, which are due to evaporation and bank storage, are controlled by meteorological and hydrological laws. Some of the most significant depletions will occur at Lake Powell, because of its size and its principal role in the management of the river.

Management strategies which result in a decrease of water quality will be equivalent to a loss of water. The tradeoffs between water degradation and water allocation need to be quantified for a given management action.

Available water supply will continue to be a composite of (1) the river flow resulting from the ever-changing climate, and (2) the water losses from natural processes responding to selected management actions. To maximize water supply, it will be necessary to distinguish carefully between the effects arising from natural processes both before and after a decision has been implemented.

e. The Lake Ecosystem in Transition.

The answers to several research questions may be arrived at by viewing Lake Powell as an ecosystem composed of interacting physical, chemical, and biological processes. The numerical quantities reflecting these processes are changing, and the source of change is either

in the natural cycle, in human action, or both. With respect to any observable change, it is often unclear whether its origin lies in the natural cycle or in man's manipulation.

Lake Powell is in the process of being transformed from a river to a lake. The major flow down the lake still follows the historic channel. The deposition of sediments along the bottom is in its initial phase. The circulation patterns in the lake which determine the oxygen concentration are still in a state of flux. The distribution of suspended matter, including salts, responds to these circulation patterns and to the distribution of biota in the lake.

The biological productivity of the lake, in turn, responds to the distribution of salt and to the circulation patterns and thus is undergoing change. At the present time, the lake is still "healthy." That is, it is "well mixed" and well oxygenated. Presently, the water leaving the lake is less saline than is the water entering, because of chemical precipitation processes.

The degree of control exerted by man on natural processes is much larger at Lake Powell than at most other lakes. Since Lake Powell was constructed for multiple purposes, it is controlled by response to demands outside the lake region. As a result, the conditions of the lake are not optimized in terms of any single use; in particular, the response of the lake to these controls is not optimum for recreation and aesthetics.

It should be possible to determine how much the lake system and its condition respond to a given action in water management and how much its response is part of a natural cycle arising from past actions. First, however, it is necessary to understand the interconnection of the lake subsystems and the workings of the ecosystem under change.

Research findings of the LPRP now provide a good description (baseline data) of the subsystems of the lake. An understanding of the modus operandi of the lake is now within reach. These data will also assist in understanding the interaction between recreational use and attendant deterioration of the lake as a recreational resource.

The region around Lake Powell has many spectacular parks and monuments. The opportunities for Lake Powell recreationists are extensive. Recreational services of the area are some of the most important income- and employment-generating assets within the local economy. A variety of urban society benefits, such as transportation facilities, are by-products of the economics of recreation. The future productivity of this asset largely depends on the quality of the recreational services offered.

It becomes important to understand the interaction between the current productivity of the asset, as measured by recreational use, and environmental deterioration which accompanies the use.

f. Alternative Futures for Energy Production in the Region. The current crisis in fuel supply and power shortage is imposing changes in the previous accommodation among energy development, alternative uses of water resources, and environmental quality. The Lake Powell region has rich coal resources in the Kaiparowits, Black Mesa, and Four Corners areas. Pressure is increasing for rapid development of these resources to satisfy rising regional and extra-regional energy demands.

The principal ways in which the Lake Powell region might contribute energy would include (1) export of coal to other areas for conversion into electricity; (2) burning of coal within the region to produce electricity for export to other areas; (3) gasification of coal for export of synthetic gas to other areas; (4) liquefaction of coal for export of synthetic oil to other areas; and (5) provision of water for nuclear electric power production.

The choice of any one of the alternative energy production modes has different implications for the region in terms of potential conflicts among the users of the area and the benefits derived. Given a particular demand for energy production in a particular mode at a specific site, the impacts can be studied for alternative futures.

Present technology of electrical powerplants requires cooling water in the production of energy. Water-cooled, coal-fired powerplants use 15,000 to 20,000

acre-feet per year of water for each 1000 megawatts. If western coal is to be burned in sufficient quantities to ease the "energy crisis," one way to avoid heavy consumption of scarce water resources in the Colorado River system would be to transport coal out of the Basin for power production elsewhere. However, this alternative is not presently preferred by the power industry which has already secured rights to water and coal resources of the region. If a large complex of mine-mouth powerplants is constructed in the Upper Basin during the next two decades, the water demand for power production could easily require all the presently uncommitted surface water of the Upper Colorado Basin. Water which might have been allotted to supplement irrigation, or used for other industries or recreation, will instead be diverted to energy development. Indeed, it may be necessary to reallocate present water commitments from other uses to energy production.

The construction of additional powerplants in the Lake Powell region will impact in a number of ways depending upon economic, legal, and political constraints. These constraints may restrict or eliminate alternate management choices in the region.

In terms of the political framework for the Upper Colorado River Compact, increased demand for energy production may lead to further disappointment of rural and urban upstream users whose participating irrigation projects may become much more doubtful enterprises. And, the reduction of Federal subsidy for such projects will have important implications for the development of rural and urban portions of Upper Basin states.

Legal institutions and constraints, such as nondegradation requirements of the Clean Air Act of 1970, the necessity of preparing environmental impact statements under NEPA, compacts, regulations, and court decisions allotting water in Lake Powell and water underlying the Kaiparowits Plateau, and rules allocating jurisdiction among Federal, State, and tribal governments will affect the type of resource development that will occur in response to increased demand for energy from the Lake Powell region. Availability of water from Lake Powell in light of current commitments, for example, may affect choices between air-cooled and water-cooled plants, between location of plants near underground water (if any)

on the Kaiparowits Plateau, or between export of coal to other areas for conversion into electricity and on-site conversion. Similarly, Federal and state air quality standards may affect location of pollution-creating generators both in clean-air areas in which degradation is prohibited, and in areas such as Los Angeles, which are currently so polluted that further industrial activity is discouraged.

The air quality of the Lake Powell region is excellent. This is an aesthetic resource which has a very high value because of its scarcity. The wilderness of the canyonlands is unmatched in the world, and when this wilderness is degraded, the resources of the country are diminished. The stack emissions of coal-fired powerplants near the lake will degrade the air in this area. Research findings of the LPRP to date help provide the baseline data of air quality. When the Navajo powerplant comes on line in 1974, various characteristics of the air quality will degrade because of sulfur dioxide, nitrogen oxides, and particulates, including heavy metals, and these can be properly assigned as to the source.

Policies at the national and interregional level concerning power production are being considered which have serious implications to the environmental health of the whole Basin, of which the Lake Powell region is merely one part. Large-scale strip mining, the detonation of possibly hundreds of nuclear devices for natural gas stimulation, and the conversion of oil shale, in situ, to liquid fuel, will have a large effect on transportation, land use, water quality, water allocation, air quality, and urbanization of the whole region. Proposed energy policies will impact the local Lake Powell region, as a part of the Basin, and thus will affect to a large degree the decisions for power production in the region itself. The prospects of sweeping environmental changes in the Lake Powell region arise from energy policies generated outside the Basin coupled with a decision-making vacuum within the region.

II. PRODUCTS OF THE PROPOSED RESEARCH

A. Research Reports Initiated by LPRP (Topics)

1. Rationale. The Lake Powell Research Project expects to produce specific research applied to immediate needs. In the past 2 years, LPRP attempted to bring its growing knowledge to bear upon several specific policy problems being posed to decision-makers. In Years 3 and 4, LPRP intends to expand and formalize this activity by producing a number of interdisciplinary reports. These products are intended to serve the concerns of the interests and abilities of the researchers and the decision-making needs of user groups.

The preceding section of this proposal outlined some major themes related to the forces of change in the Lake Powell region. The LPRP has projected some specific topics related to these themes which concern various user groups in the region in need of research results for decision-making. The interdisciplinary reports prepared on these topics will draw upon the broader research underway upon the themes, but will be more narrowly focused and will be presented in language and form which user groups need and can best use.

All members of the Project are assigned to work on these topics. The responsibility of completing a final report and the managing of the associated research tasks for a particular topic has been assigned to two senior investigators of the Project, who will be called Chief Scientists. The Chief Scientists are responsible to the Project Steering Committee, and are guided by the appropriate Coordinator.

The following section outlines nine integrated reports to be produced during Years 3 and 4. The section after that outlines briefly one additional topic which is under consideration but to which the Project is not firmly committed at present. Doubtless, new topics not discussed here will emerge in the course of future work.

2. Nine Report Topics Selected by the Project

a. Level and Distribution of Income and Wealth Generated by Resource Development. This proposed report of the LPRP will present findings concerning the

degree to which the local population of the Lake Powell area will benefit from ongoing economic development. Local expectations include increased incomes and local consumer spending which stimulate the local economy and improve the standard of living of local residents, and increased revenues from taxes and royalties which improve and modernize the educational, governmental, and other public service institutions. Preliminary findings among the Navajo indicate that these expectations are not being met. The questions the investigation will attempt to answer are the following:

- (1) What is the increased income level accruing to local Indian and non-Indian populations?
- (2) What proportion of the income dollars are spent locally, regionally or outside the region?
- (3) What are the factors which promote or inhibit growth of the local economy?
- (4) What are the amounts of tax and royalty revenue which are returned to the local areas, as opposed to the region or even more distant metropolitan areas?
- (5) What are the factors which promote or inhibit the development of local public institutions?

The Project hopes to be able to determine whether local expectations are being met and whether, in the event they are not, the failure is due to the peculiar position of the tribe within the region and nation generally or to factors which affect reservation and non-reservation populations alike.

Project findings to date are very tentative but indicate that the expectations of local populations, both White and Indian, are not being fulfilled. Increased incomes are being achieved but many of the new jobs are not going to local people. Instead, skilled workers from outside the area take these jobs and change the homogeneous quality of local communities. Much of the income is spent outside the area either by the consumer himself, or by retailers who must purchase their supplies in cities at some distance.

The Navajo Tribe benefits from the Navajo Generating Station and Peabody Coal Co. by receiving royalties and lease rents. But it is the state and county who tax so that a sizeable proportion of the revenues flows out of the Reservation proper. There is also the danger that

the area will soon become reliant upon a single industry--energy production--if the national energy crisis persists. The possibility of a "bust" after construction jobs are finished must be considered. The requirements of energy production are antithetical to the tourist industry, and a declining tourist industry means that few permanent jobs will be available after the powerplant's construction phase is over.

The Navajo Tribe is concerned not only with immediate developments in the Lake Powell area but also with the implications the Project findings may have for contemplated developments of coal gasification plants on the Reservation. Social Science Coordinator Levy is maintaining direct contacts with the office of the tribal chairman, and with the Agricultural Products Authority. During Years 3 and 4, close liaison will be maintained with the Navajo Office of Manpower Resources. Reports will be sent to the above-mentioned offices and also to the Bureau of Indian Affairs and the Navajo Health Authority.

The LPRP subprojects assigned to this topic are Anthropology, Sociology, Economics, Law, Political Science, and Kaiparowits Resources.

The data required to answer questions (1), (2), and (5) will be gathered by conducting surveys of households and local business establishments. Questions (4) and (6) will be addressed by examining terms of the contracts for the Navajo Generating Station and the prospective Kaiparowits Project, and comparing them with expected arrangements in the region generally.

The LPRP has appointed Jerrold Levy (anthropology) and Alan Kneese (economics) as Chief Scientists who will coordinate the Principal Investigators in connection with the research of this topic, and will be responsible for the completion of the report.

b. Institutional Framework for Environmental Assessment and Planning. Current efforts at environmental protection are far less cohesive than the environment itself. Whereas the environment is a composite of countless interrelated natural substances and processes, the institutional responses to environmental concern are largely isolated and unsystematic.

Typically, under the environmental impact statement procedure, a development-oriented entity analyzes its own plans and makes a self-serving declaration as to foreseeable environmental impacts. Opposing interests, often with limited technical expertise, protest and attempt to defeat or alter the proposed action. The systematic and objective assessment of cumulative and geographically remote impacts is not encouraged by this adversary procedure, in part because there is no third-party institutional arbitrator in the picture, except the courts, which are ill-equipped to engage in ongoing program planning or assessment.

Environmental planning, to the extent it can be said to exist at all, is segmental. It is oriented primarily toward either specific performance standards or individual projects. The integration of land, air, and water planning is a recognized need, but not an accomplished reality.

The setting and enforcement of environmental controls suffers from these deficiencies which exist in the planning and assessment functions. The public will support effective controls and strong enforcement actions only if those efforts appear to be part of a coherent strategy based on shared values.

The need for innovative change in the institutional framework for environmental protection is currently most vividly demonstrated in the Colorado River Basin.

The institutional framework for effective, coordinated, and comprehensive environmental assessment and planning does not exist in the Colorado River Basin because dominant public institutions and private interest groups have had very little incentive to date to allow it to exist. Environmental assessment and planning are being carried on in a fragmented fashion by a number of separate organizations. Environmental policy, in large part, emerges from the bargaining engaged in by diverse interests both at the stage of adopting standards and enforcing them.

Formidable plans for large-scale mineral extraction and energy production in the Upper Basin are beginning to move stage-center in front of this institutional backdrop. The program environmental impact statement on

oil shale development issued by the Department of the Interior and the National Academy of Sciences' study on strip mining suggest the enormity of the cumulative impacts which may be forthcoming. Even those general studies, however, do not assess the regional impact of combined, full-scale coal and oil shale development. There exists no framework whereby the environmental consequences are regionally assessed by multidisciplinary research and integrated into a sustained program of regional planning.

This proposed research report will (1) describe the present, fragmented framework for environmental assessment and planning; (2) indicate the scientific knowledge of the regional ecosystem required to allow intelligent, comprehensive environmental assessment and planning; (3) relate the impact of certain recent environmental legislation such as the National Environmental Policy Act, the Clean Air Act, and Water Quality Amendments upon environmental assessment and planning; and (4) indicate the barriers and incentives to innovation toward a more comprehensive institutional framework. Expanding on this last goal, the proposed report will indicate some possible innovations, such as regional planning arrangements, and Basin-wide compacts. The incentives which might lead to such changes will be catalogued along with the blocks which might be placed in the way of innovation. Interstate rivalries, urban-rural cleavages, agency jealousies, under-developed decision-making capabilities of some actors including Indian tribes and rural peoples, all can be expected to mitigate against establishing a comprehensive framework.

Numerous questions may be addressed in this proposed report, including the following:

- (1) What relationship is there, or ought there to be, between natural-ecological systems and human-managerial systems with respect to the subdivision of the Upper Colorado Basin into environmental assessment and planning units?
- (2) What alternative environmental assessment and planning units are available to policy-makers, given multiple political jurisdictions and the configurations of natural ecological boundaries?
- (3) How informative is the experience of river basin commissions with respect to environmental assessment and planning, and how applicable

- is the river basin commission model to the Colorado River Basin?
- (4) What incentives are needed to make viable each of the sets of institutional alternatives which appear available for environmental assessment and planning in the Colorado River Basin?
 - (5) What mechanisms could be developed to improve the flow of information in decision-making related to environmental assessment and planning?
 - (6) To what extent, if any, ought the assessment, planning, standard-setting, and standard-enforcement functions of environmental management be separated and lodged with different institutions?

The research report will draw upon various subprojects. The Political Science Subproject will describe (1) the interaction between various actors and participants in environmental assessment and planning, including Federal agencies, states, local governments, courts, and private interest groups; (2) the impact of environmental impact statements upon decision-making; (3) the formulation and review of impact statements on a number of energy facilities; and (4) how information on air and water quality is brought into decision-making. The Kaiparowits Resources Subproject will provide an in-depth analysis of the environmental consequences of one large electrical energy complex. The Anthropology and Sociology Subprojects will supply information on the planning and decision-making processes of Indian tribes and rural populations. The Law Subproject will contribute to the analysis of some of the many legal rights and claims which bear upon environmental decision-making.

Case studies of current resource decisions with massive environmental consequences will display the operation of recent environmental legislation. Data from the Law, Political Science, Sociology, and Anthropology Subprojects will contribute insight into various participants' attitudes toward innovation.

The Air Quality, Plume Analysis, Cultural Eutrophication, Shoreline Ecology, Heavy Metals, Water Budget, Sedimentation, Physical Limnology, and Lake Geochemistry Subprojects will define the environmental data which must be accommodated by new institutional arrangements

and more effectively utilized by participants in decision-making.

The proposed report can be utilized by a number of actors within the Lake Powell region:

- a. Indian nations; for example, the Navajo Tribe may desire to introduce environmental assessment and planning into its own political framework;
- b. Citizen groups which seek to improve citizen involvement in environmental decision-making;
- c. Decision-makers who are preparing to evaluate their own processes of environmental assessment and planning and who need information to formulate recommendations for incremental change in existing arrangements or who desire to propose new and innovative arrangements for regional assessment and planning; these include decision-makers at all levels of government--local, state, regional, and Federal.

The Project has assigned the Principal Investigators of all subprojects to work on this topic, and has appointed Helen Ingram (political science) and Eric Walther (atmospheric physics) as Chief Scientists to organize the research and accept responsibility for the completion of the final report.

c. Institutional Decision-Making and Resource Allocation. Public institutions play principal roles in allocation decisions with respect to water and related resources in the UCRB. Water is a common pool and flow resource requiring public management because it cannot be captured for a single use without having an immediate and often detrimental effect for other uses. Moreover, Federal and state laws have long recognized the public character of water supplies. Public involvement in water resource decisions also rests on the historic role of Federal and state governments in its development of water resources for purposes of generating economic and social values for a given local population. By their very nature, such arrangements tend to persist: individuals and groups require a settled understanding of public policy for purposes of resource planning. On the other hand, the persistence of these arrangements may have a decidedly negative effect in that they may impede the realization of other social

values that are generated by new social or economic conditions and are subscribed to by large numbers of people.

It is important, furthermore, to recognize that decisions with regard to water use have a decided impact on the manner in which other resources are used. Thus, for rational decision-making to occur, an awareness of the implications of one set of decisions for options with respect to other resources should be promoted. The institutional arrangements for making decisions should therefore arrange the flow of information among participants in the decision-making process with respect to all inter-linking resource relationships. It should provide opportunities for careful examination of a reasonable range of alternatives based on a calculation of value tradeoffs for the various interests within the region. Such flows of information and postulation of alternatives will not provide answers to what are basically value questions, but they may lead to more informed and far-sighted decisions.

From an examination of the historic patterns of decision-making within the UCRB, it is clear that the principal mode has been a bargaining process among competing interests. Where there were sufficient incentives for compromise, e.g., the passage of the Colorado River Storage Project Act, the competing local interests compromised their differences and were able to establish a united front. Similarly, the states (except Arizona) were sufficiently complementary that they could agree to a compact that provided the terms of the Boulder Canyon Project Act.

The cast of characters involved in water resource decision-making will include many of the same agencies that have exercised considerable influence in the past, but the questions of new or increased social demands, e.g., aesthetics and energy, may bring new forces into play. These forces will be represented in the decision-making process, and new arrangements may have to be created to accommodate them. It is clear, for example, that certain new institutional arrangements are already making their influence felt in water resource decisions. One of these is the increasingly skeptical attitude with respect to investments in water resources for purposes of irrigation agriculture. This skepticism is

found in increasingly higher interest rates utilized in calculating financial feasibility of irrigation projects, higher standards for determination of favorable cost/benefit ratios, and Presidential willingness to impound funds that have been authorized. A further example is the access to the courts made possible by the activities of environmental groups that are willing to challenge developmental agencies and interests. The National Environmental Policy Act (NEPA) has played an important role in making such challenges possible by requiring environmental impact statements to be made on proposed Federal developments.

It is clear that new major forces are having a dramatic impact on the decision-making process having to do with the resources of the UCRB. The environmental movement has created important political issues with respect to protection of scenic wonders of the UCRB. Further emphasis has been placed on possible destruction of the natural environment: the relatively pure air of the Basin; the biological communities affected by developmental activities; water quality and potential degradation resulting from various forms of pollution (heat, human waste, plume deposition, etc.). Increasing energy demands in the Southwest and throughout the United States have created new pressures for development of the coal, oil shale, and water resources of the region. Food shortages in the United States and throughout the world may create renewed demands for irrigation agriculture development throughout the West. International commitments, notably to Mexico, are creating new incentives for examining the allocative mechanisms presently in operation in the entire Colorado River Basin. All of these forces are impinging on the scarce resources of the region at the very same time that there is almost universal realization that the basic water resource is over-committed.

Along with these trends relevant to the specific Colorado River region, one must also consider the changes occurring in the general political framework of the nation. Two changes seem immediately relevant. The first concerns the increased interest in planning at both the national and state levels. It appears inevitable that legislation will soon be passed by Congress authorizing support for state planning. Moreover, the Federal government is increasing its emphasis on regional planning.

A second change concerns the general allocation of authority for problem-solving. The Nixon administration and many other administrations outside the Federal government have encouraged revenue-sharing as a profitable arrangement for managing public programs required by the public. The adoption and implication of such arrangements might dramatically alter the character of decision-making in the UCRB.

The multiplicity of interests and decision-making centers in the American political system means that decisions tend to reflect an accommodation of interests through a process of bargaining. It also means that changes tend to be made incrementally rather than in accordance with a clearly delineated statement of goals, priorities, and plans. While planning and careful analysis may provide a greater impact to the decision-making process in the future, they will not supplement the basic mode of decision-making. It is important, therefore, to examine the incentives and constraints that influence the various interests in the region and nation to make decisions of a given character. Only by changing the incentives and the "payoff" for major interests can the character of the output of that decision-making process be altered.

Among the important questions to be addressed in this analysis are the following:

- (1) How do the various interests, Federal planners, state officials, utility interests, and local water users in the region perceive the future in terms of the allocation of scarce resources? Do they perceive increased urban development, development of coal and oil shale resources, increased importance for the tourist industry, for agriculture, etc.?
- (2) In what ways are these interests investing in the future by means of investment in facilities and research? To what extent are they prepared to shape the decision-making results by an input of accomplished results and information?
- (3) What roles do they expect Federal, state, local, and private funding sources to contribute to the realization of the region's goals? How will various mixes of public and private investment affect the allocation of scarce resources?

- (4) To what extent will the current and future competition for scarce water resources create incentives for opening up agreements of a historical nature to a fundamental reconsideration of those decisions? Will various interests find it to their advantage to challenge such decisions as the Colorado River Compact and subsequent agreements?
- (5) Will general shifts in the responsibility for public decision-making impose on the states now responsible or create new opportunities for innovative roles for allocating resources? How will their re-allocations of responsibilities alter the character of the resource product? What interests will gain advantages from such new arrangements?
- (6) If the character of decision-making is fundamentally altered, e.g., to give greater weight to environmental or energy interests, what compensatory mechanisms will operate to lessen hardships created by such new policies? Who will be the beneficiaries of these compensatory programs and policies? For example, if the Navajos are induced to allocate a portion of their water allotment for energy development, in what ways will they be compensated?
- (7) How will changes in the institutional structures of the nation and the region provide access for new interests that have previously competed less successfully for a realization of benefits? Will the greater access to the courts fundamentally alter the bargaining process, particularly in the direction of greater environmental protection?
- (8) To what extent will advantage be taken of developing technology or extra-regional resources to meet the challenges of accommodating to scarce water resources? What will be the terms of the accommodation, e.g., of increases of supplies developed through weather modification, desalinization, or inter-Basin transfers?
- (9) What incentives will exist among present water users to make adjustments in water use? To what extent will changes in economic conditions create inducements to economize in use or to change to higher uses? How will changes in the legal structure lead to such accommodations?

The subprojects involved are Law and Political Science. The Project has assigned the Principal Investigators of these subprojects to work on this topic, and has appointed Dean Mann (political science) and Charles L. Drake (geology) to accept responsibility for the completion of the final report.

d. The Implications for Federal Indian Policies of Accelerated Economic Development of the Navajo Indian Reservation. There is a sophisticated interplay between Federal Indian policy and the development of reservation-located resources in the Southwest. A study of this interplay is the focus for an integrative report by the Law and Anthropology Subprojects. The development of water and coal resources in the Lake Powell region presents planners with some unique problems not found in other parts of the country, due to the fact that much of the coal resource, a significant water right, and much of the land and local population are Indian.

Because Indian tribes stand in a unique relationship to the Federal government, Federal Indian policy of necessity mediates the relation between Indian tribes and the non-Indian population. As a consequence, Federal policy decisions regulating Indian affairs are affected by demands for resource development in Indian country, and, in turn, have an impact in the area of regional resource allocation and management. Changes in Indian policy will affect (1) the locus of use of natural resources; (2) the future of non-Indian communities within the region; and (3) the capability of the Navajo Tribe itself to manage increasingly complex transactions with state and county governments and with private corporations. Conversely, the emergence of impelling national or regional priorities serves to challenge the principles espoused in much of Federal Indian policy. Such challenges may negate the goals of the policy entirely or may create pressures for change and reformation.

Despite these interactions, no coherent integration of Federal Indian policy with special emphasis on its relationship to resource use and energy production has yet been undertaken. The Lake Powell Research Project, because of its interdisciplinary approach and because of the data collected in the first 3 years of the study, will be able to undertake a synthesis of the research so as to provide guidance to Federal, state, local, and

tribal decision-makers on the implications of alternate national policies. Among the work that will be relevant to this integrative project are LPRP's previous studies of the Navajo Indian Irrigation Project, Federal leasing policy on Indian reservations, and the development of Indian water rights doctrines in the courts.

The concentration on national policy seems warranted because alternate methods designed to strengthen tribal government will variously affect patterns of industrial, agricultural, and municipal use of Upper Basin water. Each choice, in turn, will have different effects upon the human populations in the area, which will create counter pressures seeking modification or reversal of policy. Modes of economic development open to the tribe may radically affect the demographic composition of the on-reservation population. National policy toward tribal government may unwittingly have an impact on such variables as Navajo fertility and mortality rates and the proportion of the on-reservation population which will be non-Indian. These demographic shifts will influence resource consumption, the nature of the local labor market, the availability of managerial expertise, and the flow of consumer spending.

The Navajo Reservation in the 1960's and 1970's provides a clear example of the interplay of forces, of legal principles, ideas of sovereignty, impacts on the Indian and neighboring populations, all with an overlay of conflicting economic demands. In the early 1960's, there began to be great interest in the energy potential of the Reservation, primarily because of its coal and inchoate water rights. The Federal government played conflicting roles during this period, and it is far from clear that its trust function was adequately acquitted. Federal Indian policy, though maturing in the direction of strengthening tribal sovereignty, had not reached the pitch of the end of the decade. Critical events took place, including the bargaining for rights to Upper Colorado River flow and the agreement to the Navajo Indian Irrigation Project.

This integrative report will explore the implications for Federal Indian policy of the Federal-tribal relationship on these two vital matters and also on the leases involving the coal gasification plants and mining at Black Mesa. The report will attempt to answer the following questions: (1) Are negotiation and

planning for reservation resources in accord with stated Federal Indian policy? (2) Are there changes in the structure or process by which the executive fulfills legislative policy that would yield closer approximation to agreed upon goals? Based on the research for the LPRP, the report will attempt assessment of the potential Federal role with respect to resource allocation on Indian reservations.

While Federal Indian policy has often purported to take into account secondary consequences of Federal action, this has been done with precious little success in the past. Indeed, in the past, policy-makers have rarely even identified the secondary and tertiary consequences of changes in Federal Indian policy and the relationship between those changes and other variables.

It is important that such a process take place so that decision-makers can be more attentive to the potential consequences of their acts. We shall attempt to trace secondary and tertiary consequences of implementing interrelated policy goals. For example, the increase in interest in tribal self-government has significant resource allocation implications.

In this section of the work, we will also integrate our study of the effect of economic development on the political authority of the tribe, particularly the power of the tribe to tax, zone, guide, and control land use on the reservation.

From our studies of such institutions as the Office of Navajo Labor Relations and from the demographic studies of Dr. S. J. Kunitz, it should also be possible to identify the links between development, changes in the employment profile on the reservation, and the effect of such changes on health, fertility, and patterns of settlement.

Federal Indian policy with respect to development will also have implications for the political structure of the principally affected states, primarily Arizona and New Mexico. Under discussion, for example, is a restructuring of local boundaries to take into account the new demands.

Given this background, the work will project various possible roles for the Federal government and potential

definitions of Federal Indian policy. The conclusions will be specifically directed at the relevance of the Navajo experience to the Bureau of Indian Affairs, the Department of Justice, the Bureau of Reclamation, the tribes, the counties, and other involved governments. It will become clearer, we think, than it has been in the past, just what consequences flow from particular economic development decisions. For the tribe, for example, we think that our study will buttress existing efforts to provide planning and controls for the development of the eastern end of the reservation. Based on the study, the tribe will have a more specific idea of its bargaining alternatives when water rights are at stake. Some of the environmental and social impacts of a new and enhanced energy development policy on the reservation will also be explored.

The proposed integrative report of the LPRP will explore the effects that several possible variations in Federal Navajo policy may have on non-Indian interest groups. The expectation is that each policy alternative will ultimately be expressed in terms of demands on the limited water resource and in some form of regulation of or restriction on the exploitation of resources on the Navajo reservation. The natural science subprojects will assess the effect each policy alternative will have on water quality as well as the effects upon the policy alternatives of limits posed by the resource itself.

The study will also trace the conflicting goals of Indian policies. Federal Indian programs over the last 100 years have had two agenda: one was directed at the underlying natural resource and the other was directed at the Indian people themselves. One agenda was implicit, the other explicit. There was, and continues to be, the strain of rehabilitation, of encouraging entry into the mainstream of reducing dependence on the Federal government. But there is also the strain rather de-emphasized, of enlarging the proportion of the public that can take advantage of the great resources of the West. Concepts of rehabilitation, of legal rights, and of equitable distribution of natural resources are usually on a collision course. Illustrative are the "termination" programs of the 1950's and the "new deal for American Indians" programs of the 1930's. The goals of the former, aiming at the total integration of Indians into the general population, were diametrically

opposed to the goals of Ickes and Collier who desired to strengthen Indian self-determination and separatism. The social science subprojects will attempt to explore the implications of a strong tribal government for the pattern of water allocation in the Upper Basin. A strong, well informed tribal government which effectively asserts its rights to water will be better able to lobby and bargain for the larger share of Federal and private financing necessary to implement those rights.

Indeed, in a basic sense, the study will seek to explore alternative futures for the Indian reservations of the Southwest. In light of the changing nature of demand for resources, vast changes in the population are taking place--vast changes in the rate of education, in the role of tribal government, and in the interests of the states.

In part, the future of the reservation is a condition of the legal constraints established in the past. The tribe is a polity with a measure of sovereignty, a peculiar and idiosyncratic aspect of the federalist terrain in the United States. The rights of the tribe and its members to the resources of the policy must be clearly understood. These rights include those to water, land, and coal and other minerals. The rights include as well the power of the tribe to alienate, through sale or lease, these essential resources.

The desirability of one policy option as opposed to another must be evaluated not only in light of legal and political difficulties and ramifications but also in terms of the extent of benefit the Navajo population will realize from the development of the natural resources.

The immediate users of this report will be the Navajo Tribe, the Bureau of Indian Affairs, the Indian Health Service, and the Solicitor for Indian Affairs of the Department of the Interior.

The responsibility for providing a completed report and for maintaining contact with the user groups has been assigned to Chief Scientists Monroe Price (law) and Jerrold Levy (anthropology).

e. Impact of Development on Demographic Structure. This research report proposes to answer some

of the questions posed by the theme "changing patterns of urban-rural relationships." It has been pointed out elsewhere in this proposal that demands on the Lake Powell region emanate primarily from extra-regional areas and institutions. Demands for natural resources such as coal and water, and for services relating to the recreation industry, are generated largely by an urban society. The increasingly intimate contact between rural populations, which until recently were relatively isolated, and a rapidly growing urban society has had a profound impact on rural population structure, family organization, economic activities, and personal values. The questions which the demographic investigation seek to answer revolve around the impact on rural Indian and White populations of the increasing penetration of their region by metropolitan influences.

- (1) What is the impact of economic development on the population size and composition of the Lake Powell region?
- (2) What relationship does development have to migration patterns?
- (3) As a result of economic development, what are the changes in fertility, mortality, and household composition in the affected populations?
- (4) Assuming alternate modes of regional economic development and/or exploitation, what effects on population growth or decline are likely to be witnessed?

The Mormons in southern Utah and the Navajo Indians in southern Utah and northern Arizona may be regarded as the indigenous people of the Lake Powell region. Both groups have lived until recently in relative isolation from the larger society. That isolation has complex roots which need not be discussed here save to point out that (1) for the White populations, it appears to have begun breaking down as a result of the Depression of the 1930's and World War II; and (2) for the Navajos, the isolation is still much more complete.

The Mormon population of southern Utah grew rapidly during the first several decades of the present century. Birth rates were high and mortality relatively low. Peak populations in Garfield and Kane Counties were reached in 1940, and since then out-migration has been greater than either in-migration or natural increase. The decline did not begin until 1960 in San Juan County,

largely as a result of a uranium boom there in the 1950's. Thus, the Mormons have begun to reveal demographic patterns which show a distinct similarity to other rural U.S. populations: a decline in births, a loss of young people, and aging of the population. With a growing dependence on, and susceptibility to, metropolitan influences and institutions, the relative isolation of rural life has all but disappeared.

The Navajos have responded to economic and social change in a somewhat different manner; indeed, they have responded in much the same fashion as populations of developing nations. As a result of public health measures, their death rate has declined to about the same level as surrounding White populations. Their birth rate, however, remains high and thus their numbers are growing rapidly, at about 3 percent per year. Unlike their White neighbors, out-migration has not increased appreciably. The population is therefore not only growing rapidly but is very young as well, about 50 percent being below the age of 20.

These differences between the populations suggest different modes of adaptation to regional and local economic conditions. Southern Utah residents hope that increased job opportunities will enable their children to remain at home rather than to seek their fortunes in the cities as is the case presently. For these relatively homogeneous Mormon towns a stemming of the out-migration represents a strengthening of the traditional Mormon way of life. These expectations may be disappointed, however, if large numbers of outsiders come into the area to take jobs. Increasingly the heterogeneity of these small communities will clearly change established social and political relationships in ways not envisioned or planned for by local leaders.

The economic isolation of the Navajo Reservation has resulted in a subsistence economy which exploits a number of fluctuating resources. In order for the Navajo family to be able to herd sheep and to engage in migratory seasonal farm labor and the like, a large extended family unit is required. Once the transition to small independent nuclear families has been made, the Navajo will be totally dependent upon steady wage work. Depletion of natural resources in the next 20 years without development of an alternate wage economy will

leave the Navajo in a more depressed state than exists currently.

The growth of local populations in areas of employment, as at the Navajo Generating Station or at sites on the Kaiparowits Plateau, will place increased demands upon existing social services such as schools and hospitals. Planning for expanded services will require accurate population projections. This study, in turn, relies upon the economic projections for the area and must take them into account. Certainly, long-range economic plans for the Lake Powell area will determine whether expanded health and school facilities will be under-utilized 10 years from now.

During Years 1 and 2 the Anthropology Subproject conducted a detailed social, economic, and demographic survey of three Navajo populations in the impact area. Comparable surveys will be conducted among several southern Utah communities in Years 3 and 4. In Year 2, the Epidemiology Subproject conducted a fertility study among two of the Navajo populations sampled by the Anthropology Subproject. During Years 3 and 4 the fertility study will be extended to include the Navajos of the Page area as well as the populations of southern Utah. An historical demography of the Navajo was completed in Year 1, and census data are available to provide historical perspective for the study communities in southern Utah.

The immediate users of these findings are the local governments of southern Utah, the Navajo Health Authority, the U.S. Public Health Service (USPHS), and the Indian Health Service of the USPHS. Reports will be sent to all of these users.

The LPRP has assigned Stephen J. Kunitz (epidemiology) and Ronald Little (sociology) to coordinate the investigations in the conduct of research for this topic, and to be responsible for the completion of the report.

f. Consumptive Water Use in the Upper Colorado River Basin. The problem of a gap between the supply of water in the UCRB and the potential demand for that water has already been identified as a major theme of Years 3 and 4 of the LPRP. In pursuance of that theme, this proposed report will present findings

concerned with the nature and consequences of impending choices between competing claimants for the presently allocated and remaining unallocated water assigned to the Upper Basin states. In this report, we will be primarily concerned with allocations for consumptive use. Where appropriate, we will refer to other integrative projects of the LPRP which are analyzing in depth particular impacts of such choices, such as on demography, distribution of wealth, Federal Indian policy, and air quality.

Initially, this report will examine the physical and legal-institutional constraints on alternative schemes of allocation. The total supply of water is obviously a major limitation. Some present allocations of water were made on the basis of overly optimistic projections of annual river flow, which were in turn based on data gathered during an abnormally wet cycle. New projections of water supply will be made in view of (1) long-term mean streamflow and its variability through time and space in the UCRB, (2) losses from the streamflow system due to reservoir construction and management, (3) augmentation to the Basin's natural surface-water supply, and (4) groundwater sources.

From these projections, a number of alternative futures will be qualitatively analyzed. These alternative futures will be derived from combinations of demands arising from the following management choices: (1) large-scale mineral extraction and processing, (2) electric power production from mine-mouth coal-fired plants, (3) increased agricultural productivity, (4) better downstream water quality to fulfill demands from agricultural users and Mexico, and (5) increased export of water to metropolitan areas outside the Basin. From the analysis of alternative futures, we expect to be able to describe the effect upon a particular sector arising from a given management choice. For example, we would evaluate the impact of increased irrigation, given a certain combination of demands for water export, power production, and mineral extraction and processing. The impact would be the change in quantity and quality of the water arising from increased agricultural production.

Court decisions, compacts, statutes, and treaties place very different types of limitations on distribution of UCRB waters. Thus the requirement of environmental

impact statements prior to undertaking certain government projects, the existence of Indian water rights and Federal commitments to the Navajo Indian Irrigation Project in exchange for Indians limiting assertion of those rights, current institutional arrangements for allocating water within the framework of the Colorado River Compact, and treaties regarding salinity levels in Colorado River water delivered to Mexico pose legal, political, and/or economic barriers to the rearrangement of water priorities in response to changing demands. This report will identify these and other legal-institutional constraints, the extent to which they discourage a change of current priorities among water users, and the changing political framework within which decisions to alter these constraints will be made.

After analyzing possible alternative combinations of uses of water in the UCRB, this report will consider the wider social impacts of each choice within the region. Some of these effects are mediated by dynamics of Lake Powell itself. Thus, a decision to satisfy demands for a larger water allocation for energy production may require maximization of water storage in the lake, a question to which this report will address itself. If greater water storage should be required for that purpose, preliminary studies by the LPRP already indicate that a change in lake level will affect the lake system and shoreline quality in ways that in turn will affect recreational opportunities at the lake. A preliminary study of this effect has already been made (see Part II.B.1.B of this proposal). Other impacts include (1) effects on income distribution within and without the region of such choices as one between export of water to Southern California for agricultural production and construction of coal gasification plants within the region which will increase the salt concentration in the river and render the water less fit for agricultural use; (2) effects on the demography of the region of choices which favor regional industrial development over agricultural production or export of water for other purposes; (3) political effects on the Navajo Tribe and on rules allocating jurisdiction over Reservation activities of choices which result in (a) reduction of Federal subsidies to NIIP or (b) increased non-Indian activity in the region; and (4) all the collateral effects of a choice of increased energy development, such as those on air and water quality and scenic values. The report will further

consider whether these impacts of alternative water allocations are actually taken into account in the decision-making process, as when environmental impact statements are prepared.

The findings of the last 2 years provide much of the baseline data. For example, the effect of certain consumptive uses upon the physical, chemical, and biological processes in Lake Powell is already known. The data gathering on evaporation and bank storage, of Lake Powell, is not completed, due to the long lead time in instrumentation on a lake of this size. However, the instrumentation is now completed, and the data collection should be finished after one additional year. The findings of the Law and Political Science Subprojects provide a substantial amount of the baseline data needed in these fields, e.g., water rights, legal constraints, etc.

The data required for the analysis of alternative futures will be analyzed by the Economics, Hydrology, Geochemistry, Law, and Political Science Subprojects, as a single group, in order to create the final report.

The LPRP has appointed Gordon Jacoby (hydrology) and Carole Goldberg (law) as Chief Scientists who will coordinate the investigation in the conduct of research of this topic, and who will be responsible for the completion of the report.

g. Prediction of Future Significant Changes in the Lake Powell Ecosystem. The Lake Powell ecosystem comprises the lake itself, its water, aquatic biota, sediment, the surrounding shoreline with terrestrial biota, the overlying atmosphere, and man on the lake and the shore. The various elements in the ecosystem are interconnected in a complex manner, and changes in one part of the system often induce important changes in other parts. Since the construction of Glen Canyon Dam, the ecosystem has been changing rapidly. A large river is being transformed into a lake, with a subsequent recreational use increase. Towns have been constructed near the shores. Construction of the Navajo Powerplant Complex (a generating station, a mine, a railroad, and transmission lines) has been completed on the southern shore, and even larger powerplants are contemplated for the northern shore. Roads have been built for access to new marinas on the lake and to

various energy facilities. The creation of the lake has changed the ecosystem of the area substantially, and now man's activity near or on the lake is making further changes.

There are demands from without the UCRB for certain values within the UCRB. These demands include energy production and transportation, recreation, agriculture, and associated demands for water quality and quantity. Because the amount of water storage in Lake Powell is a large fraction of the total water storage in the UCRB, a large demand made from without the Basin for resources in the Basin often results through a corresponding management decision in an impact on the Lake Powell ecosystem. For example, the recreation capacity of the ecosystem is very large, but the quality of recreation depends on the lake level fluctuations, which in turn depend upon the hydroelectric power production at the dam and on water delivery downstream. Recreation value also depends upon air quality, especially visibility sufficient to see and enjoy distant vistas, but this is potentially compromised by energy production. A third example is the ability of the dam and the lake capacity to control floods and guarantee agricultural water. A fourth example is the effect of water level which affects lake circulation and calcium carbonate precipitation into the sediments, which in turn is a major factor determining water quality.

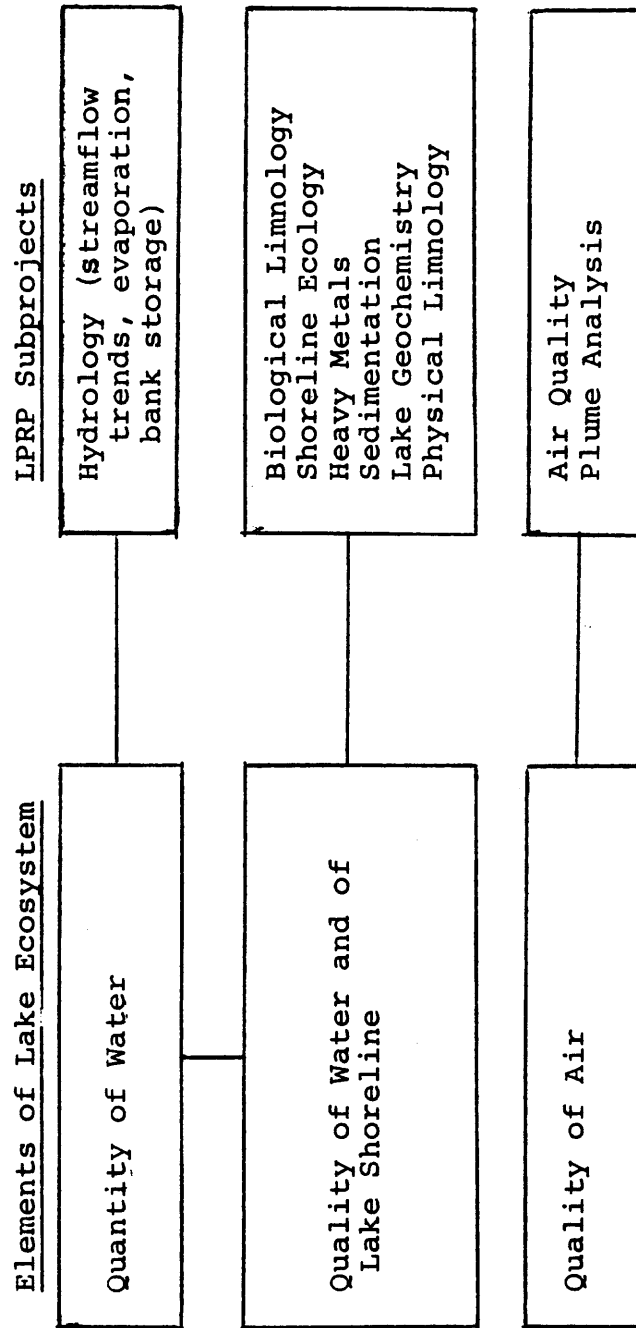
Demands like these have an impact on the ecosystem, and as the lake area adjusts to these demands, changes need to be evaluated in order to predict the consequences of a class of management decisions.

What is needed is to develop and provide quantitative insights into the modus operandi of the lake, its shore, and the air overhead. This problem can be conceived as a model, or a system, or a product which consists of graphs, tables, and equations which are the working tools of planners and managers.

Figure 1 displays the connections of the various subprojects which are assigned by the LPRP to the overall study of the lake and its surrounding environment.

The impact that Lake Powell has had on the Colorado Basin system may be gauged readily by the extent to which Glen Canyon Dam has affected the amount and type of water

Figure 1
LPRP SUBPROJECTS STUDYING ELEMENTS OF LAKE ECOSYSTEM



passing through it. Water quantity refers to the time-dependent flux of water through the lake system. As such, it is controlled by integrated inputs minus amounts lost by bank storage and evaporation, processes which were not as important before the advent of Glen Canyon Dam. Water quality means the suitability of the water for a variety of uses, which necessarily invokes the full range of human value-judgments and priorities. Nevertheless, objective indices of water quality may be assigned by measurements of suspended sediment, salt concentration, oxygen content, temperature, and nutrient loading. Any expression that depicts the value of the water in the system must include both quality and quantity parameters, although specific uses will allow the partial tradeoff of one for the other. The interface between the natural science and social science subprojects arises because of the possible alternative uses for the water in the lake system. Three such uses are easily identified: (1) hydroelectric power generation, (2) recreational use, and (3) downstream withdrawals for various agricultural, domestic, and industrial purposes. Suitability for each of these categories depends on the relative weights of the quality-quantity parameters for lake water at a given time. The ultimate aim, then, of the disciplines working on this topic is to provide the requisite technological data on water quality and water quantity.

Future changes of the ecosystem depend on natural phenomena, such as rainfall over the UCRB, and human activities, such as energy development, recreation, agriculture, urbanization, timber harvesting, weather modification, and grazing.

The research proposed by the LPRP seeks to answer questions such as the following:

- (1) What changes in the Lake Powell ecosystem would be caused by specific actions such as the addition of the Kaiparowits Generating Station? These changes should include air quality under controlled power and emission levels but variable climatic conditions, water quantity, and water quality.
- (2) What would be the impacts on the water quality by varied agricultural practices along the San Juan River?
- (3) Given various alternative futures, what would be the projection for such ecosystem characteristics as the following:

- a. Sedimentation time and place
 - b. Eutrophication of the lake regarding nutrients and biota
 - c. Fisheries production
 - d. Lake circulation patterns and salinity distribution
 - e. Mercury concentration in the physical environment and food chains
 - f. Quality of shoreline and rates of degradation and recovery.
- (4) What are the measures of the lake ecosystem interactions in regard to the following:
- a. Probability with which each action or change may be predicted
 - b. Extent to which each probability is dependent on events external to this region
 - c. Elements of the lake ecosystem susceptible to irreparable damage from certain contemplated actions
 - d. Changes in the ecosystem which are serious enough to merit a special warning to society.

The Project research has already provided baseline data on water quantity and quality, aquatic biota, shoreline terrestrial biota, shoreline physiography, lake sediment, and air quality. The change of water loss to evaporation and bank storage as a function of lake level can be roughly predicted as can also the change in water quality for known changes of salt inputs upstream of the lake. The change in shoreline physiography with lake level is predictable and the change in aquatic biota and lake dynamics with lake level can be estimated qualitatively.

The LPRP has appointed Robert Reynolds (geochemistry) and David Kidd (biology) as Chief Scientists to organize and coordinate the Principal Investigators in the conduct of research on this topic and to be responsible for the completion of the report.

h. The Recreational Carrying Capacity and Utilization of the Glen Canyon National Recreation Area. This research report of the LPRP will attempt to integrate the findings of all the subprojects relating to the recreational carrying capacity and utilization of the Glen Canyon National Recreation Area (GCNRA).

Although the term "carrying capacity" is becoming more popular in environmental assessment, it does not have a popularly understood written definition. Here, "recreational carrying capacity" is defined as the maximum number of persons engaged in a given type of recreation so that the recreation value of the area does not significantly decrease in the long run. Clearly, if a recreational resource is over-utilized, both quality and long-run availability will decline. This implies that if carrying capacity is exceeded in the short run, future carrying capacity will be reduced. Thus, it is important to understand the determinants of use from an economic study of recreation demand and area development, from the consideration of the effects of such use on carrying capacities, and finally, from the study of the physical and biological systems which determine recreation availability in the GCNRA. The proposed analysis of carrying capacity is not applied to the region beyond the GCNRA because research information on the wider ecosystem and its recreation characteristics is lacking. However, use is determined by socioeconomic variables of surrounding regions as well as the characteristics of the GCNRA itself, and these will be considered in the analysis of recreation demand.

1. The Determinants of Carrying Capacity.

In the minds of some, the GCNRA was more appealing before the dam was built; in the minds of others, it is now a better place to fish, boat, water ski, swim, camp, hike, and view the scenery. Some seek solitude, others are gregarious. Given the existing circumstances of the GCNRA, the principal effects of the natural system on carrying capacity and value of the recreational experience include the following:

a. The unique geology and aesthetic values of the canyonlands are important to all users. Exceptional air quality is a major factor in the value of the recreational experience.

b. Water level fluctuations directly affect the characteristics of the shoreline and recreational activities associated with its quality. Records of the Colorado River flow over the last 100 years indicate there will be variations of input due to natural causes. In addition, lake level will vary subject to man-made regulation. Fluctuating levels affect shoreline quality by changing its texture (generally toward less sand and more rock), increasing slumps, affecting vegetational development on shoreline and off-shore areas, and influencing the rate of accumulation of organic sediment.

c. The effect of drawdown on vegetation is a major factor in the recreational experience. Popular sandy shorelines are quickly invaded during drawdown periods by the exotic tamarisk and Russian thistle. Subsequent yearly flooding covers the vegetation with silt and periphyton. As the vegetation dies and decomposes, it influences composition and quantity of algae, which provide the base for the aquatic food chain essential for fisheries, and it may become deleterious both to fish production and to recreational use. The dead, decaying vegetation and the insects associated with it degrade the recreational value of the shoreline during subsequent drawdown periods.

d. Water quality influences the productivity of the lake ecosystem, and thus is a determinant in the production of game fish. Visual clarity is important to those engaging in water sports or simply enjoying the lake for its aesthetic value. Biological quality relates to personal and public health through the use of lake water for drinking and contact activities.

e. Sedimentation--of the main stream, in deltas of tributaries, and from surface wash into shallow depressions of the entire lake shore--affects bottom quality, which relates to vegetation production, fisheries management, and water sports.

f. Concentrations of trace elements from both natural and man-made sources have become concerns in regard to health, especially where toxic elements may become concentrated by bioamplification in a useable product, such as bass or trout, in the upper levels of the food chain.

g. A principal recreational use is fishing, because a large variety of native and introduced species is available in Lake Powell, probably because the impoundment is gradually changing from a river to a steady-state lake.

2. The Interactions between the Natural Ecosystem and Man's Uses of the Ecosystem. The principal effects of use and area development on carrying capacity follow:

a. Although Lake Powell is large, the sparseness of vegetation and ground cover, even of soil, and the aridity of the region combine to limit recreational carrying capacity. Furthermore, recreational expectations vary with the cultural backgrounds of the users. Such considerations will require development of a system of dispersion, allocation, and

regulation, particularly for overnight camping. Recreational habits (firebuilding, waste disposal, and the like) are related to impact and carrying capacity.

b. There are changes in the natural system which can be grouped under the term "cultural eutrophication." Sewage disposal is much more complex than that associated with controlled river trips on the Colorado. Along favored sandy shorelines, littering has resulted in marked deterioration. Even when fires, trash, and toilet paper are buried, wind or water erosion frequently uncovers the debris later. Campsites become trampled. With repeated misuse of sites, insect populations increase. In the environment of Lake Powell, where beauty is associated with starkness, the process of cultural eutrophication rapidly degrades recreational experience.

c. The size of the lake encourages large boats and motors which cause large waves on shore and produce noise which, in the normally quiet desert environment, becomes a pollutant. Oil and gas residues in water and atmosphere are significant.

d. The additional potential development of the large coal reserves, e.g., the Kaiparowits Plateau, will result in a marked increase in the permanent population of the area. Such increases change the seasonal use pattern and are being considered in current master planning of the National Park Service.

e. Finally, large-scale energy production within the area will most probably have a substantial impact on air quality, affecting aesthetic and scenic aspects of recreation, as well as on water quality, through airborne transmission into the lake system.

3. Utilization of the Glen Canyon National Recreation Area. Recreation demand for a particular area is determined both by the usual socioeconomic variables of population, income, and price, and by

a set of unique components which may be called the "characteristics" of the recreation experience. These characteristics are closely related to the quality parameters of the physical and biological systems in the GCNRA which determine carrying capacity. The price of obtaining recreation from the GCNRA includes costs of accommodation, travel, and license fees--in essence including all necessary peripheral expenditures. With a knowledge of demographic variables including the distribution of population in surrounding regions, an understanding of recreation demand can be obtained.

The actual levels of utilization observed in the GCNRA must also be determined by the local availability of transportation and services. Transportation facilities via air and road have been increased to provide access to the area. Few people arrive at the lake from the north via boat down Cataract Canyon. There are continuing demands for access roads across natural areas to the shores of Lake Powell. The influx of recreationists has required the provision of services from a variety of sources in the system. Many commercial establishments of bordering communities have been created and depend on the demands of recreationists for gas, supplies, equipment, food, and lodging. Concessions have been granted by the National Park Service to provide for recreationists' needs at designated sites around the lakeshore. The Park Service itself has established campgrounds, information services, access, and a variety of health and welfare services. Increased use of the lake for recreational purposes by the Navajo, whose Reservation is adjacent to many miles of the shoreline, and the search for economic ventures have resulted in plans for development of a Navajo marina. The Bureau of Reclamation provides informational and educational facilities. The Utah Fish and Game Department has to stock the lake with fish.

Recreation is almost a unique use of natural resources because its consumptive use and cost can be minimized by proper management. However, there must be recognized a correlation of intensity of use to a general deterioration of the environment, which tends to gradually lessen the quality of the recreational experience. Quality reduction might lead to reduced use and reduced economic benefit. Increased use means increased cost of monitoring and regulation by some agency. There are

serious questions as to whether the present system of a single concessionaire could function properly if the recreational pressure were increased markedly.

Similarly, although a major use of Lake Powell is for recreation, both the responsibilities of providing a quality recreational experience and of protecting the natural resource from the impact of recreational use are delegated to the National Park Service, which has little input into water-level management, a prime determinant of recreation carrying capacity.

Some of the questions to be pursued in this proposed research report are the following:

- (1) How can the varied recreational values of the GCNRA be quantified: what are they and how fast are they changing?
- (2) How can the local recreation value of a particular shoreline campsite be compared with the overall recreation value of the lake?
- (3) If recreation seasonally degrades some part of the GCNRA, how much does it recover before the next seasonal impact?
- (4) What is the effect of the national petroleum shortage on recreation in the GCNRA, its impact on the ecosystem and on National Park Service planning there?
- (5) What is the effect on recreation of new roads for energy development and tourism?
- (6) What is the relation between recreational carrying capacity and lake level? What is the tradeoff between recreation and energy production at the dam as a function of lake level?

The recreation potential of the shoreline is reasonably well known because of the mapping of shoreline physiography and studies of natural vegetation and plant succession of shoreline and drawdown zones. Data have been collected on visitation and expenditures for the various recreation sites in the GCNRA. Furthermore, information on the regional determinants of use, such as income and distance traveled to Lake Powell, has also been gathered. This material has provided a basic understanding of utilization in the GCNRA and will be incorporated into this report.

The subprojects most involved in this topic are Shoreline Ecology, Biological Limnology, Air Quality, Hydrology, Sedimentation, Sociology, and Economics. The LPRP has assigned the Principal Investigators from these subprojects to work on this topic, and has appointed Loren Potter (biology) and Shaul Ben-David (economics) as the Chief Scientists to organize the research and accept the responsibility for the completion of the final report.

i. Impact of Energy Development around Lake Powell. Lake Powell is located near the Kaiparowits and Black Mesa coal fields which are capable of supporting 12,000 megawatts of thermal electric generation for at least 50 years (see Figure 2). Lesser in magnitude is the energy represented by water of the Colorado River which is already being extracted as electricity in the Glen Canyon Dam. With growing societal demands for new energy sources, pressures to use the coal near Lake Powell to produce electricity will continue to increase. Figure 2 shows the distribution of coal reserves in the UCRB and their proximity to the power load centers in Los Angeles, Phoenix, Salt Lake City, and Denver.

Coal resources at Kaiparowits Plateau are the largest in Utah, and the third largest in the region. The costs of recovering regional coal resources are largely determined by the depth of major coal seams below the surface. Figure 3 shows that the closest large deposits of strippable coal (within 500 feet of the surface) to the southwest power load centers are the northern Kaiparowits Plateau and the Four Corners Area. It is clear that the Kaiparowits coalfields represent a very important potential energy source for at least three metropolitan load centers because of their size and advantageous mining and transportation costs.

Power developments in the Lake Powell region are already underway. The Four Corners Generating Station, near Shiprock, is operating and will be expanded. The Navajo Generating Station near Page, Arizona, is near completion and will begin operation in June 1974. A Kaiparowits Generating Station, 15 miles north of Page and 12 miles north of the Lake Powell shores, has been proposed but delayed pending review by the Secretary of the Interior. Each generating station is part of a large-scale power project, which includes coal mine

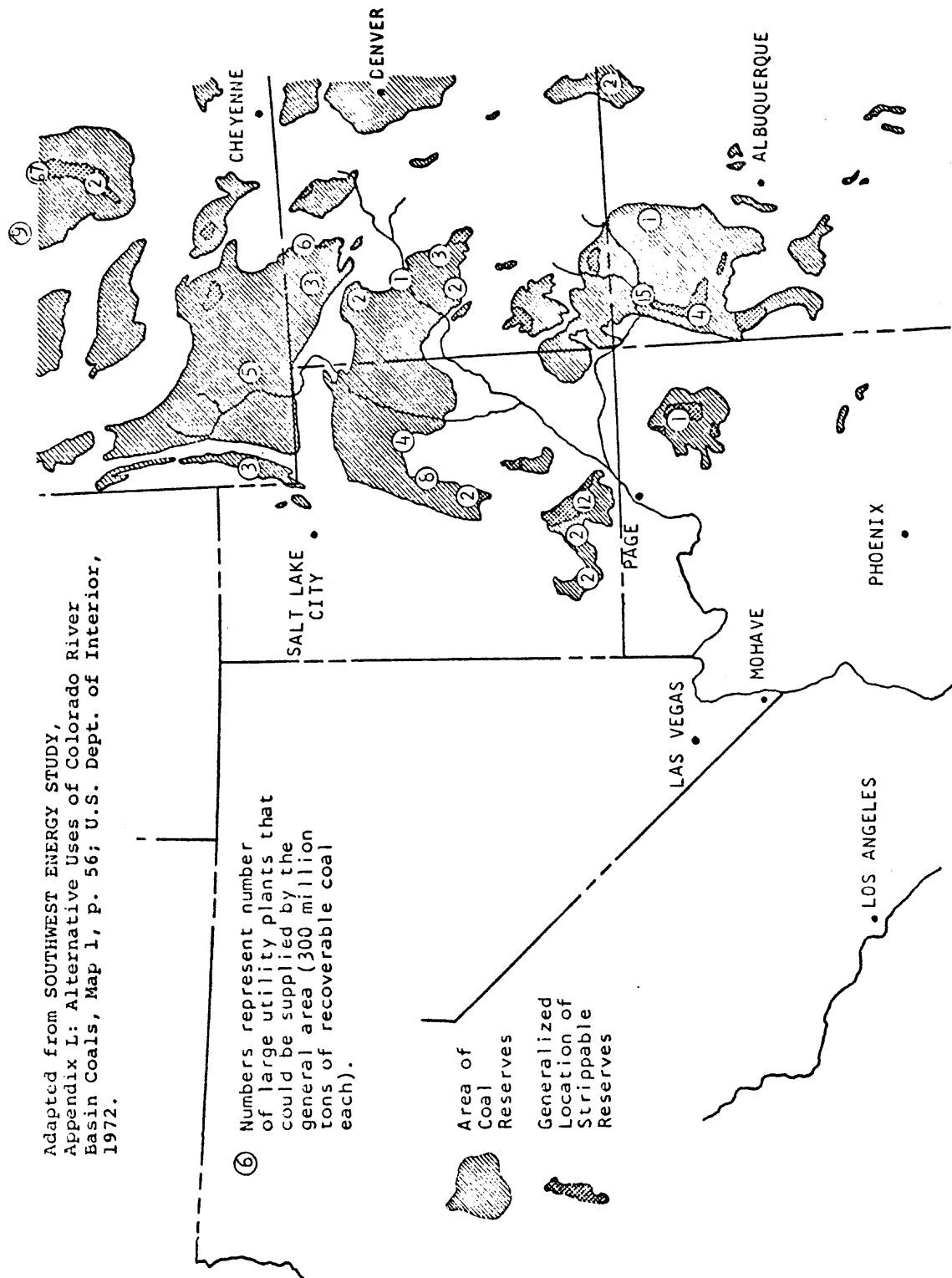


Figure 2
COAL FIELDS OF THE SOUTHWESTERN UNITED STATES

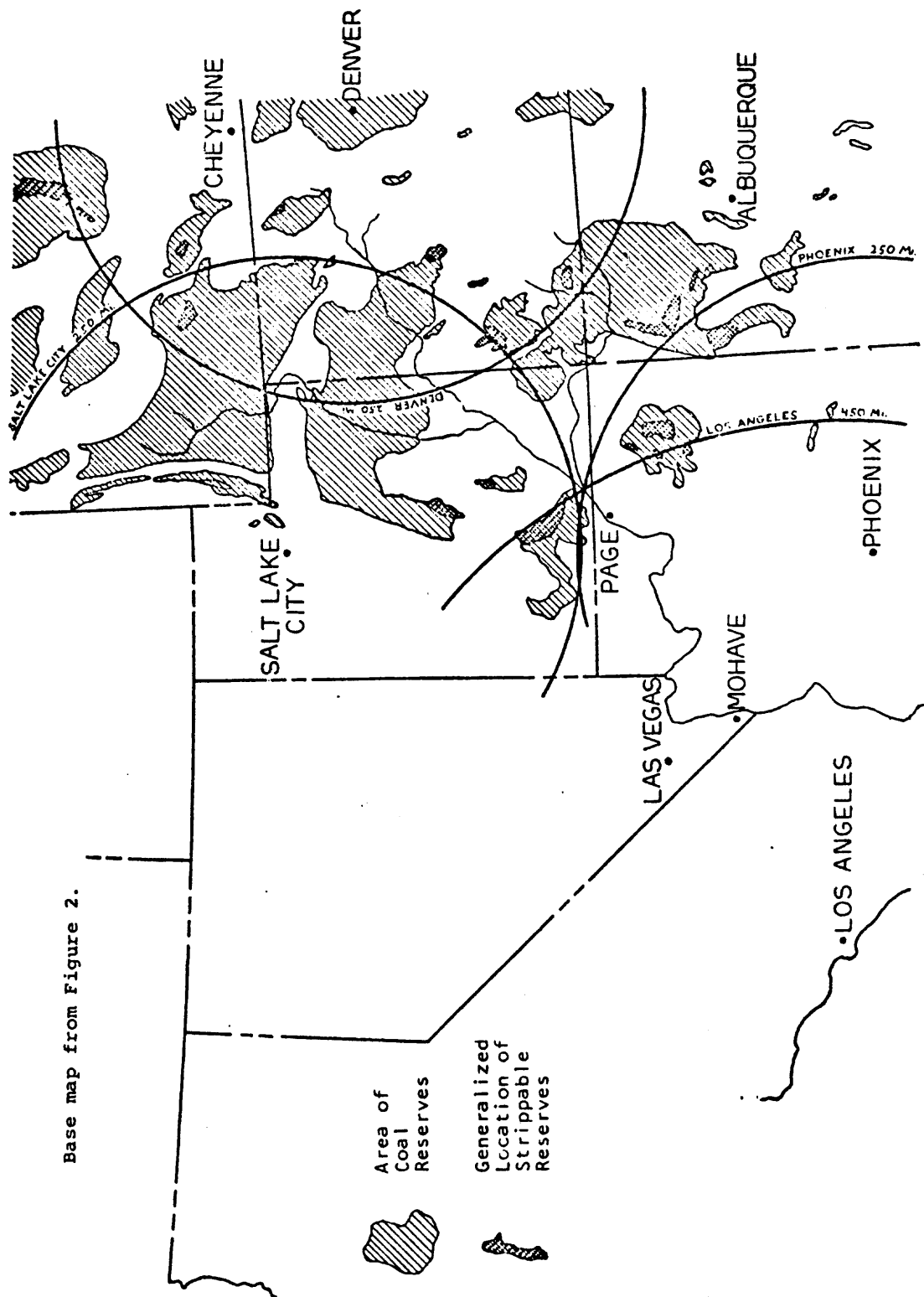


Figure 3

DISTANCES FROM MAJOR POWER-LOAD CENTERS TO THE KAIPAROWITS PLATEAU AND OTHER WESTERN COAL FIELDS

operation, transport of coal, ash disposal, water supply system, and transmission lines.

The coal for the Navajo Generating Station is strip-mined on Black Mesa and transported to the powerplant by railroad. If approved, the Kaiparowits Project will produce coal by deep mining methods and will burn it at mine-mouth plants. Resources Co., a consortium of public and investor-owned utilities (Arizona Public Service Co., the Salt River Project, Southern California Edison Co., and San Diego Gas & Electric Co.) proposes to build the Kaiparowits Generating Station and holds leases on the coal resources in the southern part of the Kaiparowits Plateau (18 million tons per annum is the planned production). There are additional plans for coal exploitation and power production in the northern part of the Plateau. Utah Power and Light and the Intermountain Consumer Power Association have filed for Escalante River water rights to supply a large generating station to be built about 10 miles south of Escalante.

Utah Construction and Mining Co. and Nevada Electric Investment Co. have leased coal reserves in the Alton coal field just west of the Kaiparowits Plateau. Nevada Power Co. has proposed construction of a large coal-fired plant near Las Vegas, using coal from the Alton field. This coal would be transported by a slurry pipeline similar to the method used between Black Mesa and the Mojave plant.

The extensive exploitation of the coal in the Kaiparowits region for power production will likely require more water than is available from Utah's uncommitted allocation of the Colorado River water. The management of regional water resources and power development of the Kaiparowits-Lake Powell region are inextricably linked.

Patterns of power development and coal mining in the Four Corners area and the Page area are set. Further regional impacts now depend upon the extent, if any, to which the Kaiparowits Plateau is exploited for its resources. The course of future environmental quality and industrialization of the area now depends on decisions about how and to what extent Kaiparowits coal is to be managed. The Lake Powell Research Project will identify the major resource and environmental features of the Plateau, where the opportunity to chart alternative futures still exists.

The issue of developing the Kaiparowits Plateau reserves greatly concerns the resident and nearby populations, especially the communities of Page, Glen Canyon City, Escalante, and Panguitch. The attitudes of these local populations toward power development in the Kaiparowits Plateau will be one of the major thrusts in the research.

The LPRP will consider benefits to be derived from alternate production modes, and will consider potential conflicts among users of the area. For example, electric power production tends to cause a higher emission of contaminants and a greater consumption of water than the alternative future of coal gasification. Coal might also be transported outside the area for power production elsewhere by constructing more railroads or slurry lines.

There will also be an effort to examine other demographic aspects of increased energy production, including the loci of development of associated communities, the relationship of improved transportation infrastructure, and recreation-related settlement. Analysis will be made of the relationship between industrialization and demographic change on the Navajo Reservation and the relationship between such changes and modernization in tribal structure.

An important variable to be considered is site selection, which is important because (1) the distance to the source of water has a significant influence on economics of the production; (2) the site location influences the local communities; (3) air pollution models currently in use are sensitive to local meteorology and terrain features; (4) the impact on the lake system has a component, the deposition of materials, which depends on the distance from the lake and direction relative to prevailing winds; and (5) the possible visual impact of construction and pollutants on recreation will be influenced by the site selection. The location of the site relative to the coal mine will also influence the economics of the operation. The actual selection will also be strongly influenced by political and institutional factors.

The plant design will also determine the type and degree of impact which may be expected. Present plans

for coal-burning power assume wet-cooling towers which consume 15,000 acre-feet per year per 1,000 megawatts of installed capacity. However, a dry-cooling tower would consume only a small fraction of this, but would cost more to install, consume more coal, and the operating costs would be higher. Hybrid systems would consume amounts intermediate between the dry and wet towers.

Another design choice would be the use of groundwater (if available) rather than surface water from Lake Powell. This choice could reduce or eliminate potential conflicts among Upper Basin water users. Other design choices might involve the amount and type of pollution-control devices which would influence the nature of potential recreation values or alter the legal constraints. The LPRP will consider a number of such choices as alternative futures for impact analysis.

Changes in water quality and quantity as a result of competing uses will be involved in the alternative futures. Energy needs may put a call upon existing uncommitted Utah water, for example, curtailing or limiting future recreational and agricultural uses of Colorado River water.

Legal institutions and constraints will affect the type of resource development that will occur in response to increased demand for energy from the Lake Powell region. Legal variables include the nondegradation requirements of the Clean Air Act of 1970; the necessity of preparing environmental impact statements under NEPA; the contracts, compacts, statutes, regulations, and court decisions allocating Colorado River water; the legal principles governing the management of the groundwater underlying the Kaiparowits Plateau; and the rules allocating jurisdiction between Federal, state, and tribal governments. Federal and state air quality standards, for example, may affect proposals to locate pollution-creating powerplants in clean-air areas in which degradation is prohibited, as well as proposals to locate plants in areas such as Los Angeles, which are currently so polluted that further industrial activity is severely restricted.

Some of the questions the LPRP wishes to consider in this topic are the following:

- (1) In the event that large-scale water-cooled powerplants are constructed, what demands will

- this make upon Utah's water allocation rights, and what pressures will be created for the re-negotiation of the Colorado River Compact?
- (2) What patterns of land use can be foreseen, and what demographic shifts would arise from various selected alternative futures?
 - (3) What will be the effect on water quality from various selected alternative futures?
 - (4) How would the discovery of large groundwater resources in the Kaiparowits basin affect the level of coal and power production?
 - (5) What would be the effect on the agricultural base in Kane and Garfield Counties, Utah, from various selected alternative futures?
 - (6) What effects will power development have on the air quality of the region, considering various alternative futures?
 - (7) How do residents of the Kaiparowits Plateau region perceive the advantages and disadvantages to themselves and their communities of the establishment of a large-scale power and mining industry?
 - (8) What local population changes can be expected, from immigration, due to the various selected alternative futures?
 - (9) What combinations of energy resources and power load centers in the Southwest would maximize the environmental protection of the Kaiparowits Plateau?
 - (10) To what extent will jobs and capital investments in the local area, arising from the power and mining industry, survive once the coal resources are exhausted or abandoned?

The LPRP has already obtained much of the baseline data required for this topic. Data exist on air quality, water quality, the water budget of the lake, employment and income in the Lake Powell area, the institutional framework of the area, and demographic patterns. There exist data on coal reserves, leases of the coal reserves, plans for energy facilities, and surface water allocations.

The subprojects involved are Sociology, Kaiparowits Resources, Law, Political Science, Hydrology, Physical Limnology, Lake Geochemistry, Air Quality, and Anthropology.

The LPRP has assigned the Principal Investigators of these subprojects to work on this topic, and has appointed Orson Anderson and Gary Weatherford to organize the research and accept the responsibility for the completion of the final report.

3. Probable Future Report Topics. As suggested previously the LPRP will consider additional topics as the subjects for interdisciplinary reports. An example of such a topic follows.

o Multidisciplinary Scientific Research for Regional Impact Assessment

Multidisciplinary research has become an internationally accepted means of bringing scientific scrutiny to bear on complex problems. In the United States, it has gained particular credence in the fields of environmental science and policy. The National Environmental Policy Act of 1970, for example, compels all Federal agencies to "utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision-making which may have an impact on man's environment."

Underlying this national policy is the assumption that environmental assessment requires a spectrum of analysis much broader than that which any single scientific discipline can provide. The logic of that proposition is irrefutable. An environment composed of many diverse yet interactive processes is best understood by a research effort which is capable of examining a broad spectrum of elements of the processes.

Formidable obstacles stand in the way of creating, organizing, and perpetuating an interdisciplinary group to accomplish the goal of environmental assessment. We may note some of them briefly:

(1) The definition of the most salient research problems: who defines the important questions; funding agencies, investigators, politicians, business interests, the public, or some combination? The definition of areas to be investigated may change depending on a variety of factors and, as definitions and demands change, the internal structure of the research group itself is forced to change. Thus, the way problems are defined will determine to a considerable degree the composition of the interdisciplinary group at the same time as the group influences the problem areas to be addressed.

(2) The appropriate institutional framework: the advantage of having all workers from one institution

is that day-to-day communication is facilitated. The potential disadvantage is that all investigators may not be equally good. The collaboration may be nothing more than a marriage of convenience. Assembling a team of highly qualified investigators usually involves a wide geographical distribution. Logistics can become a budgetary problem. However, by choosing highly qualified investigators such that there is a smooth inter-meshing of disciplines and personalities, the results will be superior and will warrant the added expense.

(3) Applied versus basic research: there has been a continuing debate in many fields concerning the quality of the products of mission-oriented research. Such concern has important implications for individual investigators attempting to make their way in an academic discipline and may represent substantial risks:

- (a) Mission-oriented research is itself regarded as of lower status than pure or basic research;
- (b) To the extent that an investigator engages in research outside the areas defined as appropriate by colleagues in his discipline, he may jeopardize his chances for promotion within an orthodox departmental structure;
- (c) The felt need to satisfy members of one's own discipline may conflict with the goals of the interdisciplinary project.

(4) The mechanism by which integration of research findings is achieved: given the potential conflicts between goals as defined by a particular discipline and the needs of an interdisciplinary project, both conceptual and structural mechanisms must be evolved in order that competing claims may be satisfied.

These issues clearly transcend the relatively narrow bounds of the LPRP and are of more general concern to the scientific community which in the future will be asked to train students for interdisciplinary work at the same time as knowledge becomes increasingly specialized. Project workers have been interested in understanding both how the Project itself has dealt, or failed to deal, with these and other problems and in comparing it to other interdisciplinary groups. The feasibility of such a study will be explored by Priscilla Perkins and Stephen Kunitz.

B. Education Component

1. Student Participation. Most subprojects include undergraduate and graduate students on their research teams. Where the research of the graduate student is part of his thesis, not only he gains but the Project profits as well by the extra motivation, concern, and time contributed by the student. Several excellent theses have developed from the current funding. Graduate students have participated in regional and national meetings involving the Project and have frequently contributed scientific papers. They have also learned research methodology by sharing in the organizational planning and administration of a complex interdisciplinary search for answers to societal problems. Several undergraduate students have used some aspect of the LPRP for an independent study course.

2. Innovative Teaching. In addition to frequent citing of the methods and results of the LPRP during regular instruction, there are several universities that have used the LPRP as a theme of emphasis in a modified educational process. These universities include Dartmouth, San Jose State, UCLA, and University of New Mexico.

There have been earth science field trips that have visited the lake and studied the field operations of the Sedimentation, Physical Limnology, Lake Geochemistry, and Hydrology Subprojects. Environmental classes have visited Project facilities and the lake area to combine the viewpoints of both the social and natural sciences by "on-the-spot" experiences. Project scientists have been available to give informal lectures to these visiting groups. Through the efforts of the Project, government planners, administrators, lawyers, and representatives of industry have also been available to meet with visiting groups.

One of the theme topics of the Project is currently being locally supported and used by a participating university and researcher as a model for a graduate workshop to educate by participation in the interdisciplinary approach to solving a societal problem.

Commonly the Project has provided an attractive focal point stimulating undergraduates to want to

become involved in special undergraduate problems, which results in a participating educational experience of increased value to them, and may incidentally benefit the Project.

3. Seminars. The planning for the Project, the process of integration of a variety of disciplinary approaches into a proposal, the mechanism of administration, and the blending of its results into a meaningful presentation of answers to real problems represents an example of a social-political-natural science investigation of a regional ecosystem. Major interests in one subsystem can be supported by integrating the available evidence of other areas. Therefore, parts, or the whole, of the LPRP provide an excellent theme for seminars. These have been conducted in a variety of departments, at university level, and will be conducted at the national level as represented by the Lake Powell and Lake Tahoe Environmental Sciences Symposium at the AAAS meetings in San Francisco during February 1974.

Seminars have been presented to local environmental groups (Moab, Utah, and Flagstaff, Arizona), universities, state offices (for example, California State Department of Conservation in Sacramento), the Navajo Indian Tribe, and scholarly societies (American Geophysical Union, International Water Resources Association, and the Arizona Chapter of the American Water Resources Association). It is expected that the seminar activity will be greatly expanded in the next funding period.

C. Products Specifically Requested by User Groups

1. Reports. The Project will respond to requests made by a user group, for a report on a current problem, if the subject matter is approved by the Steering Committee. As an example, the Project was invited to write a report on the environmental effects of restricting the maximum lake level of Lake Powell. This request was made by Congressman Wayne Owens from Utah, through the Director's Office at the National Science Foundation. It was stimulated by the controversy over admitting Lake Powell waters into the Rainbow Bridge National Monument.

The Project responded by issuing a Progress Report on this subject. The report is entitled "Some Consequences

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of Restricting the Maximum Elevation of Lake Powell," and was written by O. L. Anderson and P. C. Perkins, incorporating contributions from Senior Investigators. It is intended that this report will be revised and issued as a final topical report when the hydrological and economic data of the Project are completed. The Chief Scientists assigned to complete this report are Priscilla C. Perkins and Gordon C. Jacoby.

2. Letters. The Project is often asked to respond to public inquiries about special problems in the Lake Powell area. A typical example is the case where a resident of Utah asks the Park Superintendent of Glen Canyon National Recreational Area for information on water quality of Lake Powell. The Park Service refers the query to the Project, and a response is made directly to the citizen from the Coordinators' Office.

D. Future Product Utilization Plan

1. Rationale. The aim of the LPRP is to supply useful and needed information about the interaction of man and his total environment in the Lake Powell region. It is obvious that a great deal of information already exists. However, much of this information has limitations in the sense that it does not satisfy wholly the aims of the LPRP. Since collecting information has high costs, and because information is an important resource in the political process, agencies and groups have concentrated on acquiring that body of knowledge which serves their goals. More comprehensive, disinterested, interdisciplinary appraisals which put the existing narrow, specific information into a broader perspective have not previously been available, with a few singular exceptions. Further, not all of the groups in the region have had the resources to obtain the information they needed in order to weigh the implications of resource allocation decisions.

2. User Group Identification. The users of the information generated by the LPRP fall into the following broad categories:

- (a) Interest Groups, ranging from environmental to

developmental; for example, the National Water Resources Association, The League of Women Voters, The Sierra Club, and Friends of the Earth.

(b) Industries, including public and private utilities, coal, construction, oil, and other extractive enterprises, and recreation merchants and concessionaires.

(c) Elected Public Officials, including Congressmen, Governors, State legislators, Mayors, and others.

(d) Federal Agency Officials, included in such agencies as National Park Service, Bureau of Reclamation, Bureau of Outdoor Recreation, Public Health Service, Bureau of Sport Fisheries and Wildlife, Bureau of Indian Affairs, Bureau of Land Management, Environmental Protection Agency, etc.

(e) State Agency Officials, including resource planning agencies for water and land use, fish and wildlife departments, health departments, etc.

(f) Local Officials, including regional planning agencies, planning and zoning commissions, city managers, etc.

(g) Tribal Officials, such as the Navajo Office of Manpower Resources and the Navajo Health Authority.

(h) Universities and Professional Groups, such as the American Association for the Advancement of Science, the University Council on Water Resources, and many other more disciplinary associations.

3. Receptivity to Information. We have no illusion that additional information alone can alter fundamental differences concerning resource allocation and use. At the same time, groups should be made aware of the broader implications of their positions and proposed actions. Thus the basis of conflict may shift, and a different order of rationality may infuse the decision-making process. Groups may come to weigh their positions in terms of long-range alternative futures rather than short-range benefits.

In order to have an impact upon user groups, the LPRP must take into account some of the basic factors which determine whether or not a particular user group will seek and use new information:

- (a) The relevance and proximity of new information to a question or problem of immediate concern to the user group and the time available to the group;
- (b) The interest and level of expertise of the user group to understand and interpret new information;

- (c) The credibility of the source of new information as is deemed accurate and not unfavorably biased.

The categories of user groups identified above include great variation in priorities within available time and levels of competence. It is impossible to fill the needs of all categories to the same degree. However, the LPRP intends to deliver a number of products with a range of different foci to potential user groups. The media and packaging of information will be aimed at both laymen and experts. Further, the LPRP will endeavor to maintain the general reputation for fairness and objectivity it has begun to earn in the first 2 years.

4. Utilization Process. Just as the LPRP has directed different products towards different user groups, it intends to vary the type of communication according to receptivity of different potential users. For example, the provision of information to Indian tribes may be on a day-to-day informal basis as resource questions confront them. On the other hand, formal bulletins and reports are a more efficient (or traditional) medium to supply information to professional groups, universities, and some agencies. It is of little utility to provide a laundry list of the possible ways in which communications may be carried on. Instead, what follows is simply an indication of some of the vehicles and activities which may be employed and the strategies which may be used to transfer information most effectively.

- (a) As part of our research efforts, the LPRP will endeavor to obtain from users their information needs and preferred means of communication. Ideally, continuous contact will establish channels of communication which can be employed in definition of issues and displays of alternatives.

- (b) As the Project has done in the past, a response will be made to specific questions posed by user groups.

- (c) The LPRP will produce a variety of formal reports and bulletins designed to provide information to user groups.

- (d) Members of the LPRP will be prepared to submit testimony at various public hearings on proposed projects and to comment on selected environmental impact statements. Members of the various research teams

identified with topics will participate in various conferences conducted on resource development allocation and use within the region.

(e) The LPRP will be willing to confer with Federal and state agencies about their own research priorities and programs, identifying whatever gaps and information needs may exist.

(f) Members of the LPRP will themselves sponsor meetings in conjunction with other groups in order to expand knowledge of the region.

5. Utilization Budget. In order to ensure the production and distribution of information to users, especially the ten integrated topical research reports described in parts II.A and II.C, certain money is set aside in the subproject budgets for travel and publication costs. All of the subproject travel budgets provide for several Project meetings each year, which will allow the various Chief Scientists to get together and work on the integrated research reports. It is estimated that about \$15,000 per year of the total Project travel budget will contribute to the preparation of these reports.

The Natural Sciences Coordinator's budget also provides \$2,000 per year for the Chief Scientists to meet in pairs and small groups for continued preparation of these integrated reports. The same budget provides \$3,000 per year for editing, duplication, and distribution of these reports.

In summary, the Project budget provides an annual utilization budget as follows:

Meetings arranged by Chief Scientists	\$ 2,000
Estimated fraction of general meeting costs, devoted to preparation of research reports (topics)	\$15,000
Estimated travel to user groups for personal consultations	\$ 3,000
Editing, duplication, and distribution of reports	<u>\$ 3,000</u>
Total Utilization Budget:	\$23,000 per year

III. MECHANISMS OF INTEGRATION

A. Interdisciplinary Approach

A comprehensive study of man's impact in the Lake Powell region requires the simultaneous analysis by numerous disciplines as described in this proposal. If the disciplines were to be applied to the Project design, research, and communication independent of each other, the result would be multidisciplinary research with unconnected findings. Such research is incapable of properly describing the related changes occurring in a complex system like the Lake Powell region.

The proper approach, proposed herein, is interdisciplinary, with all of the disciplines combining their knowledge to the analysis of the societal problem, its conceptual framework, the Project goals, the Project structure, the integration of research results, and the production of integrated research reports like those described in Section II.A.2 and II.C.1. Such an interdisciplinary approach is designed to maximize our understanding of all the interrelationships among the components of the Lake Powell region.

B. Integration by the Use of Chief Scientists

Recognizing that various disciplines converge on a special topic at different rates and with different degrees of cooperation, the LPRP has instituted a second level of authority between the Steering Committee and the subprojects which represent specialized disciplines.

Two Senior Investigators are assigned to administer each of the topics. Whenever it was possible, one social and one natural scientist were assigned to each topic. Some topics, however, were of such a nature that both scientists came from either the social or the natural sciences.

The Chief Scientists are responsible for drawing together information from all the Senior Investigators in the disciplines which may contribute to their topic. They integrate the research of such Senior Investigators so that a final report can be produced on time.

The relationships between the Chief Scientists and other elements of the LPRP are shown in Figure 4. The ten topical reports are shown in boxes next to the Chief Scientists. The report entitled "Consequences of Limiting the Lake Level of Lake Powell" is a response to a user request which is being developed into a topical report. The "Multidisciplinary Scientific Research" is a tentative report. The others have been formally selected by the Project and assigned to the individuals listed. The letters in parentheses are a key to the disciplines represented by the Chief Scientists.

Some of the topics have developed to the point where the systems analysis approach can be usefully applied, while others have not yet arrived at that point.

The Senior Investigators involved in each of the topics will seek to apply the systems analysis model which has been developed in the past 2 years so that the Project can become progressively more integrated in the systems approach.

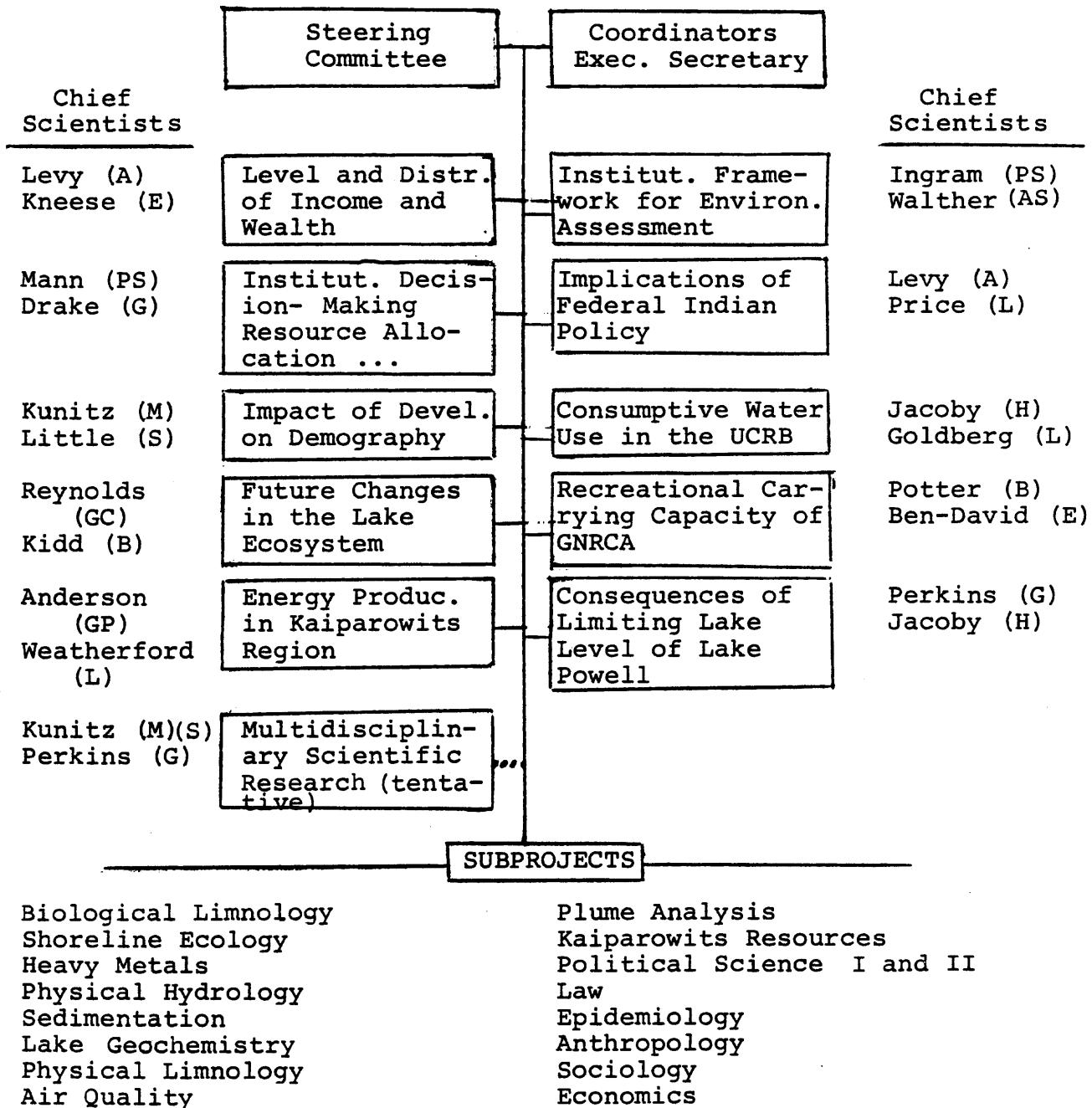
The systems analysis model will be further developed, but it will be mostly contained within the Economics Sub-project. Applications of parts of this model to various topics are expected to continue.

C. The Systems Model

The first 2 years of the LPRP emphasized the study of baseline data and the construction of a comprehensive systems model for the analysis of problems related to the development of water resources in the UCRB. Special emphasis was given to the study and evaluation of alternative water management policies and their impacts on the Lake Powell area. The national concern for energy sources to satisfy the increasing demand for power adds another dimension to the Lake Powell area. The large coal deposits and their proximity to water sources invite pressures for the development of coal-burning powerplants and coal gasification plants in the vicinity of Lake Powell. Also, there is active petroleum exploration in the area, and this activity is likely to increase. The prospects of these developments require a careful analysis of the interrelationships among the major resources in the Lake Powell area: water, oil, coal, land, people, and the natural environment.

Figure 4

CHIEF SCIENTISTS AND RESEARCH TOPICS IN THE LPRP STRUCTURE



Legend: Disciplinary Specialties of Chief Scientists:
 A - Anthropology; AS - Atmospheric Science; B - Biology;
 E - Economics; G - Geology; GC - Geochemistry; GP - Geophysics;
 H - Hydrology; L - Law; M - Medicine;
 PS - Political Science; S - Sociology

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The Systems Analysis Subproject in the first 2 years was charged with the development of the systems model to determine the impacts of alternative water management policies. The objective of this second phase (Years 3 and 4) is to integrate the new aspects of resource utilization into the simulation model developed in the first phase. Now that the various subprojects have become reasonably integrated, this systems analysis will be carried out by the total Project.

The LPRP integrates a large number of disciplines and subprojects in order to study the Lake Powell area and to develop a framework for the analysis of alternative futures. The different research tasks can be categorized into four major groups: (1) data collection and the estimation of relationships in and among the different subsystems; (2) construction of a local impact model integrating the subsystems; (3) construction of a macro impact model for the Colorado River Basin states; and (4) evaluation of alternative futures for given management decisions utilizing the simulation model allowing for the legal and political constraints.

Most subprojects are involved in the collection of data and the estimation of relationships in the first task. The total Project has the responsibility for the other three tasks.

The local-impact simulation model developed in the first phase of the LPRP transforms alternative decisions related to water management into a set of physical, social, economic, and environmental consequences. The choice of methodology arises out of the specific physical and social relationships being modeled and the objectives of the modeling. In phase I the major emphasis was on water management decisions as the action variables and on Lake Powell and its immediate environment. The local simulation model will be enlarged in the second phase to allow for a wider range of management decisions which may then be transformed into regional macro-impacts.

This wider range of management decisions relating to the Lake Powell area includes, for example, water allocations in the UCRB, lake level requirements, coal-burning powerplant developments, coal gasification plants, development of new marinas, new highway development near

the Kaiparowits Plateau, etc. Each one of the management decisions will then be transformed into a vector of action variables which in turn appear as exogenous variables such as quantity and quality of water inflows into Lake Powell, recreation demand, government expenditures in the region, hydroelectric power production levels, coal mining levels, consumptive use of water in the different uses, and land use patterns. The effect of exports of hydro and thermal electric power, regional water allocations, and commercial interregional trade including recreation, as determined by the local simulation model on the Colorado Basin as a whole, will be estimated by the macro-impact simulation model (see Figure 5). This is the systems model which is the present framework of the LPRP.

The local-impact simulation model includes three subsystems: lake system, land use system, and a socio-economic system (see Figure 6). Each of the subsystems includes a large number of relationships describing the subsystem. In addition, the model includes relationships connecting the subsystems. The model is essentially a recursive system, but contains sub-sets of simultaneous equations which are jointly determined. Some of the variables determined within the model are used together with the exogenous variables as independent variables in other equations. Some of the dependent variables in the model are included in the final vector of local impacts. The wider range of management decisions to be analyzed requires special attention to questions related to changes in local assets resulting from alternative decisions. Increased electric power production may reduce coal reserves in the area. Power production, at the same time, might, in addition to the provisions of current employment and income, also increase some long-run assets like plant and equipment or might affect education of employees by advancing their skills. Long-run impacts which could be considered as investments for future income should be evaluated separately from current impacts especially when determining long-run local effects involving changes in regional assets. As short-run impacts resulting from the management decisions, we will consider variables such as income, employment, health effects, social effects, aesthetic effects, etc. The long-run local impact will be changes in area assets such as water, coal, land, environment, physical plant, education, roads, and accumulated wealth.

Further details of the systems model will be found in the Economics Subproject proposal itself.

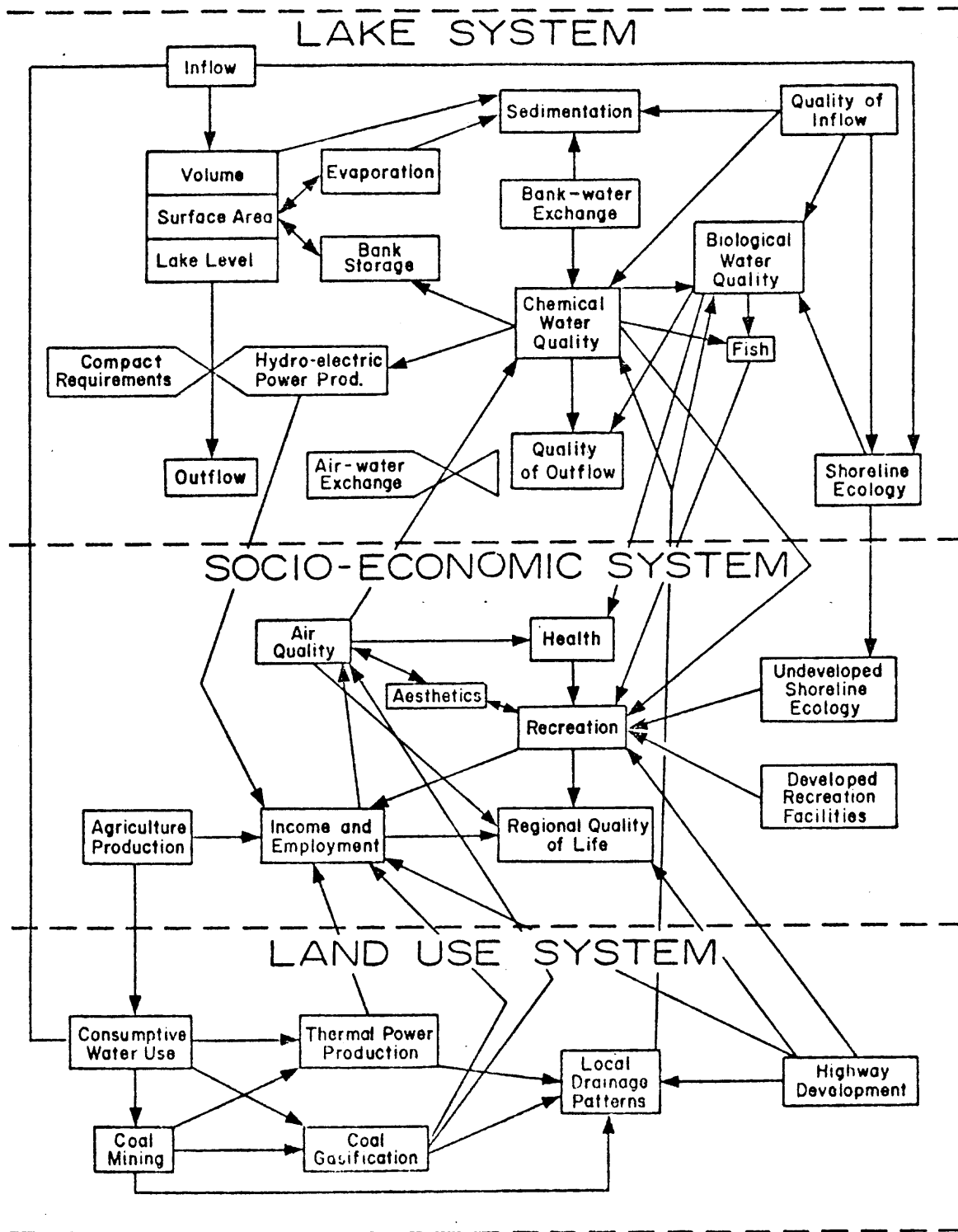
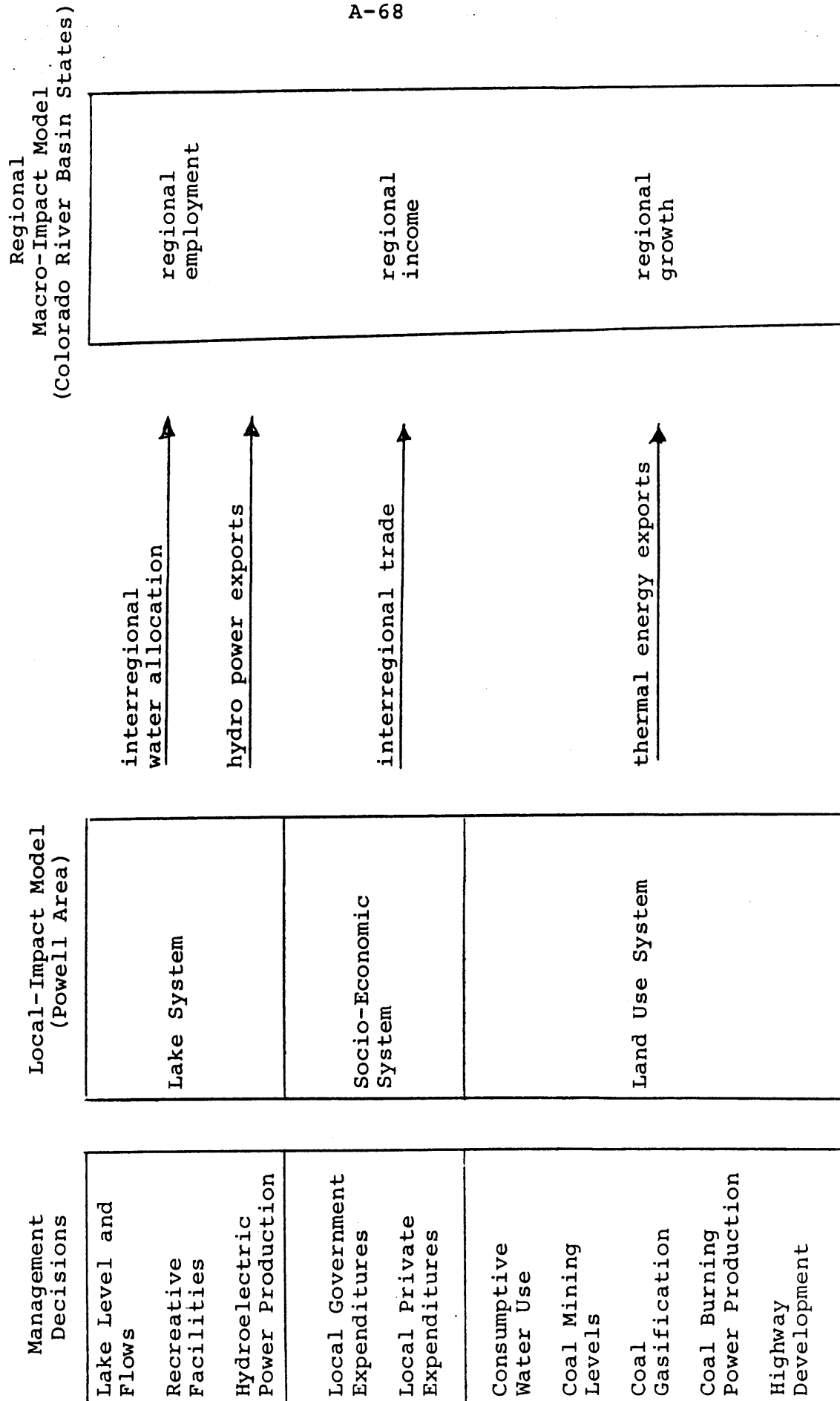


Figure 5
LOCAL IMPACT MODEL

Figure 6

THE SYSTEMS ANALYSIS FRAMEWORK



IV. MANAGEMENT

A. Administration

1. Organization. There are two management functions within the Project: policy decisions and executive action. Policy decisions are made by the Steering Committee, and executive actions are carried out by the Coordinators. In addition, the Project has created an intermediate authority consisting of the two Coordinators and two members elected from the Steering Committee, called the Executive Committee.

Day-to-day problems concerning the Project are solved by actions of the two Coordinators. However, more serious policy issues are referred to the Steering Committee. If an immediate action is necessary on a policy question, the Executive Committee makes a decision on the problem, since it is not feasible to call frequent meetings of the Steering Committee, whose members are located in several states. The recommendations of the Steering Committee, or the Executive Committee acting in its place, are executed by one of the Coordinators or by the Executive Secretary.

The Steering Committee has assumed responsibility for (a) directing the evolution of the Project; (b) the approval of new senior personnel on existing subprojects; (c) the development of new subprojects; (d) the elimination, consolidation, or realignment of old subprojects; (e) related budget decisions; and (f) the release of publications and publicity.

At the present time, the Steering Committee is comprised of experts from a wide spectrum of disciplines and professions, including political science, medicine, geochemistry, geophysics, geology, biology, anthropology, atmospheric sciences, and economics. The Steering Committee is chaired by the Coordinators, who alternate chairmanship of Project meetings. The present members of the Steering Committee are shown in Table 1.

The Coordinators' Office has three positions: (a) Coordinator of Social Sciences; (b) Coordinator of Natural Sciences; and (c) the Executive Secretary. These offices are held by Jerrold E. Levy of the Department of Anthropology at the University of Arizona, Orson L.

Table 1

LAKE POWELL RESEARCH PROJECT STEERING COMMITTEE

Anderson, Orson L. CO-CHAIRMAN	Geophysicist University of California, Los Angeles
Ben-David, Shaul	Economist University of New Mexico, Albuquerque
Kunitz, Stephen J.	Physician and Sociologist University of Rochester, New York
Levy, Jerrold E. CO-CHAIRMAN	Anthropologist University of Arizona, Tucson
Mann, Dean E.	Political Scientist University of California, Santa Barbara
Perkins, Priscilla C. EXECUTIVE SECRETARY (ex officio)	Geologist University of California, Davis
Potter, Loren D.	Biologist University of New Mexico, Albuquerque
Reynolds, Robert C.	Geochemist Dartmouth College, Hanover, New Hampshire
Walther, Eric G.	Atmospheric Scientist Northern Arizona Society of Science and Art, Flagstaff

Anderson of the Institute of Geophysics and Planetary Physics of the University of California at Los Angeles, and Priscilla C. Perkins, presently at the Department of Geology of the University of California at Davis.

The overall coordination between the Project and the National Science Foundation is performed by Anderson. His other responsibilities are listed in Table 2. The responsibilities of Levy and Perkins are also presented in Table 2.

Also shown in Table 2 are the names of Senior Investigators of the Project.

The term "Senior Investigator" is used to designate those investigators who have responsibility for scientific research on subprojects. The term "Principal Investigator" is used to designate those scientists who have responsibility between the participating institutions and the financial office of the National Science Foundation.

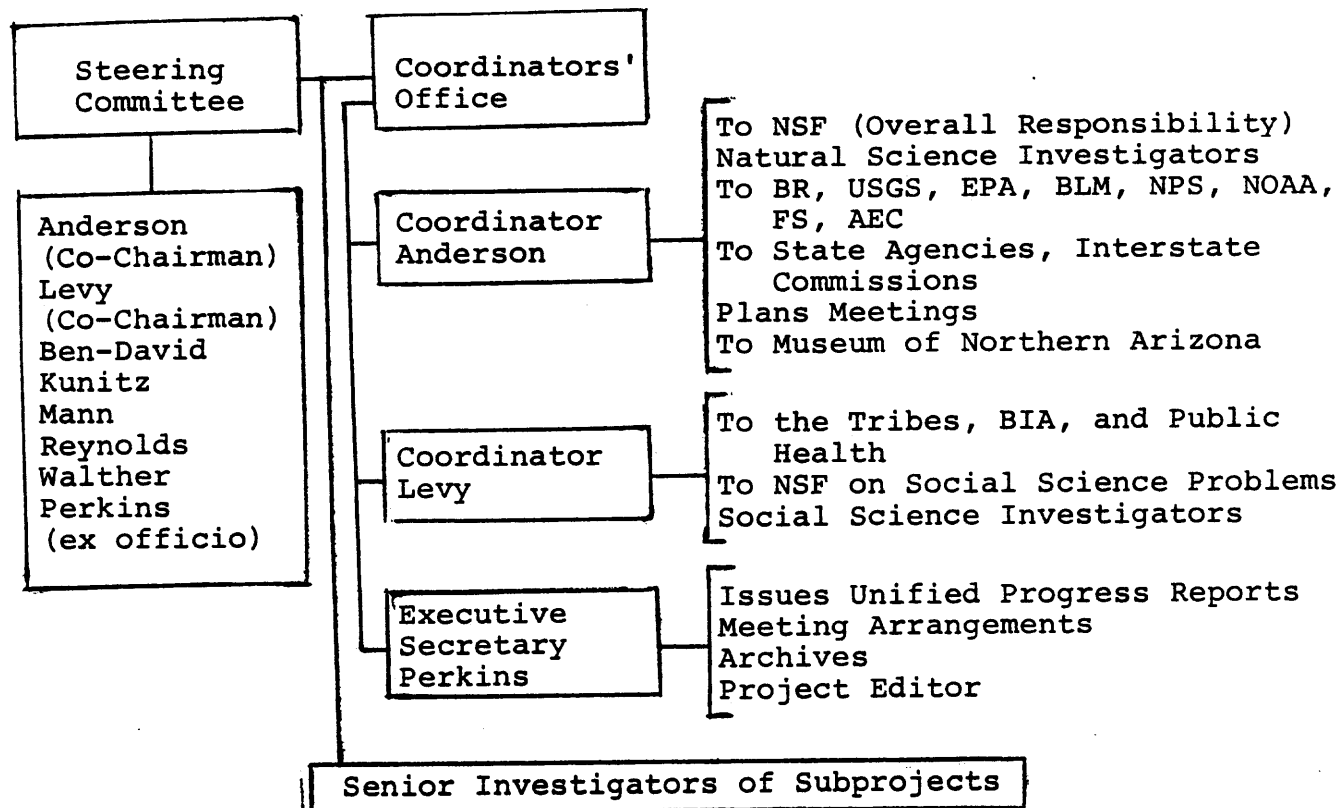
In addition, the Project uses the term "Chief Scientists" which refers to Project investigators responsible for the direction and preparation of the ten integrated research reports.

The Principal Investigators of each subproject submit their budgets and proposals to the appropriate Coordinator, who prepares them for consideration by the Steering Committee. The Coordinators schedule the times of submission and revision, and they perform the first step in negotiations between the National Science Foundation and the Senior Investigators. As a result of this negotiation, the Coordinators are prepared to recommend priorities and suggest the level of the budgets.

Subproject budgets are transmitted to the Steering Committee as received from the Principal Investigators. The Steering Committee has the responsibility to review, deny, adjust, or confirm the individual budgets. The judgment of the Steering Committee in this decision is guided by the relevance of the subproject to the Project's problems, themes, and topics. It is also guided by the timing of results and relevance to other subprojects. After the budgets and proposals are approved by the Steering Committee, Project members submit

Table 2

ADMINISTRATIVE STRUCTURE OF LPRP

Social Sciences

Ben-David, S. (E)
Cortner, H. (PS)
Goldberg, C. (L)
Ingram, H. (PS)
Kneese, A. (E)
Kunitz, S. (M) (S)
Levy, J. (A)
Little, R. (S)
Mann, D. (PS)
Price, M. (L)
Robbins, L. (A)
Schulze, W. (E)
Weatherford, G. (L)

Natural Sciences

Anderson, O. (GP)
Drake, C. (G)
Hansmann, E. (B)
Jacoby, G. (H)
Johnson, N. (G)
Kidd, D. (B)
Malm, W. (AS)
Perkins, P. (G)
Potter, L. (B)
Reynolds, R. (GC)
Stockton, C. (H)
Walther, E. (AS)
Williams, M. (AS)

Legend

A = Anthropology
AS = Atmospheric Sciences
B = Biology
E = Economics
G = Geology
GC = Geochemistry

GP = Geophysics
H = Hydrology
L = Law
M = Medicine
PS = Political Science
S = Sociology

proposals to the National Science Foundation through normal institutional channels.

Institutions participating in the PLPRP are shown in Table 3.

2. Evolving Project Structure. It has been pointed out above that the Steering Committee assumes responsibility for major policy decisions.

Such responsibility, lodged in a body that meets several times a year, poses problems and risks. It accentuates the distinction between policy as made by the Committee and policy as made de facto by the Committee's executives, the Coordinators, in the process of day-to-day decision-making.

When decision-making has been centralized, the Project has gained in its ability to respond rapidly to demands made by outside agencies. On the other hand, such centralization has at times allowed an unpopular decision to be interpreted in terms of inter-personal relations rather than in terms of what the real issues involve. When unpopular decisions have been made by the Steering Committee on the other hand, personal hostility has been diffused, allowing attention to be focused more on the issues.

Such a committee is cumbersome, however, especially when the nine members are scattered in eight different institutions across the country. Important matters that need to be decided upon quickly and cannot be handled by the Coordinators alone thus must wait on a mail or telephone poll of the Committee for resolution. To facilitate decision-making and to keep the Coordinators objective and responsive to the group, a subcommittee of two members of the Steering Committee was developed in the spring of Year 1 (1973) to advise the Coordinators when it was not necessary to poll the entire Committee. Though not without difficulties, the solution appears to have been reasonably successful in attaining the desired results. The ability to avoid hasty decisions in a project such as this would appear to be more important than the ability to respond immediately to crisis situations.

Currently, the most important issues of concern to the Steering Committee are related to the evolution of

Table 3
PARTICIPATING INSTITUTIONS

<u>Institution</u>	<u>Subproject</u>	
	<u>No.</u>	<u>Title</u>
Arizona State University Tempe, Arizona	16	Sociology
Dartmouth College Hanover, New Hampshire	5	Sedimentation
	6	Lake Chemistry
	7	Physical Limnology
John Muir Institute Berkeley, California	9	Plume Analysis
	17	Economics
Northern Arizona Society of Science and Art, Inc. (Museum of Northern Arizona) Flagstaff, Arizona	8	Air Quality
University of Arizona Tucson, Arizona	12	Political Science II
	15	Anthropology
	18	Social Sciences Coordinator
University of California Los Angeles, California	4	Hydrology
	10	Kaiparowits Resources
	13	Law
	19	Natural Sciences Coordinator
University of California Santa Barbara, California	11	Political Science I
University of New Mexico Albuquerque, New Mexico	1	Biological Limnology
	2	Shoreline Ecology
	3	Heavy Metals
University of Rochester Rochester, New York	14	Epidemiology

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the Project. In a body as heterogeneous as the LPRP, there is always a tension between the need for integrated work on the one hand and the internal logic of an individual scientist's investigations on the other. Generally, the Steering Committee and other investigators have been increasingly intrigued by the fact that the internal logic of the individual subprojects has tended to lead to convergence on problems rather than to divergence in many separate directions. Not unexpectedly, the convergences have not been complete; that is, not every subproject interacts with equal intensity with every other subproject. The interactions that have been developed sufficiently at this time to be committed to paper are those listed under the ten topical areas which will be covered in forthcoming Project reports. It is clear that some involve only social sciences, some only physical sciences, and some an integration of the two. By committing the time and money of investigators to the specific integrated reports, the Steering Committee has made these convergences structural as well as conceptual.

In addition to directing investigators toward the production of cooperative research reports, the Steering Committee has determined what subprojects should be added, what cut back or eliminated entirely, and what new personnel should be recruited. These changes, and the difficult decisions they have involved, are reflected in the changing profile of subprojects from the first proposal to the second, and in the amount of money allocated to each. Systems analysis has been reduced and included as part of an expanded Economics Subproject; Law and Political Science have been split into two subprojects, the latter building on what was in Years 1 and 2 the Impact Analysis Subproject; an entirely new Sociology Subproject has been added along with a study of the Resources of the Kaiparowits Plateau; and Stream-flow Trends, Evaporation and Bank Storage have evolved into a single study of Physical Hydrology more generally, to give but a few examples.

This evolving structure reflects a growing consensus among Project members that the major theme underlying the Project as a whole is the analysis and better understanding of the impact of social change on the Lake Powell region, including its human and natural resources, and the ways in which the physical setting and social

institutions of the area in turn influence--or fail to influence--the direction such change takes.

3. Project Meetings. In order to facilitate communications between investigators, consultants, and outside users, a series of meetings will be held periodically. There will be three general meetings each year. It is planned that all investigators and some consultants will attend the general meetings.

Flagstaff will be the site of two general meetings each year, because of its proximity to Lake Powell. Tucson and Albuquerque, chosen for the other general meetings, are residences for several Project members, enabling reduction of overall Project travel expense for meetings. In addition, there will be numerous smaller meetings called by Chief Scientists for work on particular topics.

One meeting per year is scheduled for the Steering Committee in Washington, D.C., to allow direct communication with the sponsor and interested government agency representatives.

Travel expenses for the general meetings for each of the Senior Investigators are given in Table 4. The Coordinators' budgets cover the meeting arrangement expenses (e.g., meeting room rentals, equipment rental) and travel expenses of the two Coordinators and the Executive Secretary. The travel expenses of all other personnel, including members of the Steering Committee, are found in the budgets of the subprojects in which they are Senior or Principal Investigators.

4. Publications and Publicity. All material being prepared for publication or public presentation must be submitted to the appropriate Coordinator for review. This includes professional papers, bulletins, project reports, news releases, and data exchange with user groups. Before reports of data are released to user groups, they are checked to ensure confidentiality for human subjects involved and are reviewed for statistical bias if the sampling size is small.

The policies guiding the method of dissemination of information through workshops, seminars, briefings,

Table 4

MEETINGS

Personnel	G: Flagstaff 6/74 and 9/74	SC: Wash., D.C. 11/74	G: Tucson 2/75	G: Flagstaff 6/75 and 9/75	G: Albuquerque 11/75	SC: Wash., D.C. 2/76
ANDERSON - SC	S-18	S-18	S-18	S-18	S-18	S-18
BEN-DAVID - SC	S-16	S-16	S-16	S-16	R	S-16
CORTNER	S-11		R	S-11	S-11	
DRAKE	S-5		S-5	S-5	S-5	
GOLDBERG	S-12		S-12	S-12	S-12	
HANSMANN	S-1		S-1	S-1	R	
INGRAM	S-11		R	S-11	S-11	
JACOBY	R		S-4	R	S-4	
JOHNSON	S-7		S-7	S-7	S-7	
KIDD	S-1		S-1	S-1	R	
KNEESE	S-16		S-16	S-16	S-16	
KUNITZ - SC	S-13	S-13	S-13	S-13	S-13	S-13
LEVY - SC	S-14	S-14	R	S-14	S-17	S-17
LITTLE	S-15		R	S-15	S-15	
MALM	R		R	S-8	S-8	
MANN - SC	S-11	S-11	S-11	S-11	S-11	S-11
PERKINS - SC	S-18	S-18	S-18	S-18	S-18	S-18
POTTER - SC	S-2	S-2	S-2	S-2	R	S-2
PRICE	S-12		S-12	S-12	S-12	

A-77

Table 4 (Continued)

Personnel	G: Flagstaff 6/74 and 9/74	SC: Wash., D. C. 11/74	G: Tucson 2/75	G: Flagstaff 6/75 and 9/75	G: Albuquerque 11/75	SC: Wash., D.C. 2/76
REYNOLDS - SC	S-6	S-6	S-6	S-6	S-6	S-6
ROBBINS	S-14		S-14	S-14	S-14	
SCHULZE	S-16		S-16	S-16	R	
STOCKTON	S-4		S-4	S-4	S-4	
WALTHER - SC	S-8	S-8	S-8	S-8	S-8	S-8
WEATHERFORD	S-12		S-12	S-12	S-12	
WILLIAMS	S-9		S-9	S-9	R	
Expenses for Meeting Arrange- ments in S-18	300	200	500	300	500	200

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Attendance Codes:

G = general meeting; SC = steering committee only

Budgeting Codes:

R = residence nearby; S-9 = travel expenses budgeted in subproject 9

and public talks is decided by action of the Steering Committee. Its decision is guided by the necessity for communicating results of the Project to the public and to the user groups.

The issuing of reports on the Project topics will be the main method of disseminating information. It is expected that these reports may be developed into books by the authors.

The final reports of the Project will be disseminated to libraries and to major user groups.

B. Schedule of Research

1. Progress in Previous Funding Period

a. Natural Sciences. During the current 1972-1974 funding period, the natural sciences group has examined the elements of the ecosystem in Lake Powell, the surrounding airshed, and the main river tributaries. The principal source of water in the reservoir is from upstream watersheds. The amount of flow in the tributaries has been correlated to tree-ring data which can be used to determine long-term means, variability, and trends. These indicate that an average amount of surface runoff is about 13 to 14 million acre-feet per year, all of which is used, legally committed, or designated to potential users. The two principal natural losses of water from the UCRB reservoir are by evapo-transpiration and bank storage. A data acquisition and lake evaporation data reduction system from a series of meteorological stations has been developed. Models of water "loss" by bank storage have been derived from data on the distribution, structure, and permeability of geologic formations. This storage currently accounts for about 7 million acre-feet. Two holes have been drilled to help measure the flow of lake water into the banks of the lake. The drilling of these holes was financed by the Bureau of Reclamation in a cooperative program of bank storage research with the Bureau.

The physical characteristics of the lake system respond to the dynamic nature of a filling reservoir, but with pulses during periods of filling versus draw-down. Convective mixing is only partially complete, with advective transport most important. Spring run-off produces a warm, overflow, dual-layered lake with a distinct thermocline and chemocline interface in contrast to an underflow density current in the winter. Lower layers become anaerobic. Precipitation of calcite

is the most quantitatively important chemical process altering water quality in the impoundment. A hypsometric model of the lake provides means of following the influx of quantities (heat, ions, sediments) through the lake system. Studies of clay mineral sedimentation have been completed. Soundings and core samplings have provided data on total and incremental sedimentation per year for either various parts or all of the lake. Location and rates of sedimentation are correlated to shoreline surface materials and contour.

Baseline indices of eutrophication of the lake, measures of diversity index of phytoplankton, and their carbon-14 primary productivity have been established for representative areas of the lake, as well as other biological measures of periphyton, biomass, coliform, and other intestinal bacteria. We have also monitored physical factors of temperature, turbidity, and light extinction; and chemical factors of conductivity and total dissolved carbon. Currently the lake is considered "mildly" eutrophic, but dynamics changes can occur as increased water levels flood shallow embayments.

Correlation between lake and land has been studied in the shoreline ecology which has provided mapping of the surface materials of the entire shoreline, the composition and biomass of the terrestrial vegetation, the seasonal succession into the drawdown zone, and its fate on flooding and decomposition. The lake-level interface, used for overnight camping and recreation, has been studied for availability and distribution of campsites.

The air-land-water interfaces have been linked, in part, by the heavy metal analyses to establish baselines prior to powerplant development. The movement of naturally occurring mercury has been defined from its inorganic source through the physical environment, the food chain, and its bioamplification in the tissues of seven species of game fish. A model predicting the impact of mercury released from coal-fired powerplants is available.

The unusual visibility and non-polluted air is part of the value of canyonland country. Baseline data and computer analyses are now available for wind speed, visual range, relative humidity, sulfur dioxide, oxidant, nitrogen dioxide, methane, aerosol size distribution and concentration and turbidity coefficient. Quantitative chromatographic

analysis has provided data on hydrocarbon concentrations in the air. Predictions of several types of emissions from coal-fired powerplants have been made.

The investigators of each of the natural science subprojects now believe the baseline data are nearly completed. Integration of both concepts and concrete information is now becoming possible.

b. Social Sciences. During the current 1972-1974 funding period, the social science group has looked at the social, demographic, political, and legal aspects of change due to accelerated development in the Lake Powell area. In most of these areas, problems of conflict between competing interests or of weighing the costs of development against the benefits to be derived from these activities have emerged as focal questions for future research.

Baseline data have been collected for the local Navajo populations and for the economic activities in the immediate area of the lake. Demographic and health characteristics of the Navajo have been determined. Studies of the Navajo Indian Irrigation Project and the Navajo Generating Station have been completed. And a study of the political processes involved in the development of the UCRB also have been finished. Much of the data pertaining to the social and economic changes at the local level are being analyzed. Gaps in the total research effort have been identified and efforts to remedy these have been proposed for Years 3 and 4.

The study of political decision-making in the Upper Basin has identified the conflict between environmental and developmental values as a crucial issue affecting all future developments in the area. The legal mechanisms by which decisions are formalized and facilitated involve emerging problems relating to the, as yet, undetermined extent Indian tribes have the power and jurisdiction to regulate the development and conservation of their natural resources. The economic future of the local area is dependent in large part upon the proportion of wealth generated by development which remains or returns to the indigenous populations. The models necessary to facilitate the analysis of the data have been identified. These and the focal research questions are utilized as the basis for research in the coming funding period.

c. Bulletin Publications. The following is a list of Bulletins of the LPRP that have been released or are in press:

o Published Bulletins

Standiford, Donald R., Loren D. Potter, and David E. Kidd, "Mercury in the Lake Powell Ecosystem," Lake Powell Research Project Bulletin No. 1, June 1973

Kunitz, Stephen J., "Demographic Change Among the Hopi and Navajo Indians," Lake Powell Research Project Bulletin No. 2, October 1973

o Future Bulletins

Weatherford, Gary D., and Phillip Nichols, "Summary and Overview of the Legislative History of the Colorado River Storage Project Act"

Walther, Eric G., Michael D. Williams, and Robert Cudney, "Air Quality and Water Management in the Lake Powell Region"

Robbins, Lynn A., "The Impact of Power Developments on the Navajo Nation"

Jacoby, Gordon C., Jr., "Surface-Water Supply and Streamflow Trends in the Upper Colorado River Basin"

d. Project Publications. The following lists of publications include reports to the National Science Foundation and articles in the LPRP Contribution Series:

o Lake Powell Project

Anderson, O. L., ed., 1971. "Lake Powell Project: ~~Collaborative~~ Research on Assessment of Man's Activities on the Lake Powell Region." Lake Powell Project Progress Report No. 1 (14 June 1971 to 15 November 1971) to National Science Foundation. Institute of Geophysics, University of California, Los Angeles. 91 p.

Anderson, O. L., ed., 1972. "Lake Powell Project: Collaborative Research on Assessment of Man's Activities on the Lake Powell Region." Lake Powell Project Final Report (15 June 1971 to 15 June 1972) to National Science Foundation. Institute of Geophysics, University of California, Los Angeles. 175 p.

o Lake Powell Research Project

Anderson, O. L., and J. E. Levy, eds., 1972. "Collaborative Research on Assessment of Man's Activities in the Lake Powell Region." Proposal to National Science Foundation. Institute of Geophysics, University of California, Los Angeles. 323 p.

Anderson, O. L., ed., 1972. "Collaborative Research on Assessment of Man's Activities in the Lake Powell Region." Lake Powell Research Project Progress Report No. 1 (23 October 1972) to National Science Foundation. Institute of Geophysics, University of California, Los Angeles, 32 p.

Perkins, P. C., ed., 1973. "Collaborative Research on Assessment of Man's Activities in the Lake Powell Region." Lake Powell Research Project Progress Report No. 2 (15 March 1973) to National Science Foundation. Institute of Geophysics, University of California, Los Angeles. 106 p.

Anderson, O. L., and P. C. Perkins, 1973. "Some Consequences of Restricting the Maximum Elevation of Lake Powell." Lake Powell Research Project Progress Report No. 3 (July 1973) to National Science Foundation. Institute of Geophysics, University of California, Los Angeles. 47 p.

Perkins, P. C., ed., 1973. "Collaborative Research on Assessment of Man's Activities in the Lake Powell Region." Lake Powell Research Project Progress Report No. 4 (26 October 1973). Institute of Geophysics, University of California, Los Angeles. 40 p.

o Lake Powell Research Project Contribution Series

- #1 Mann, Dean E., "Political Incentives in U. S. Water Policy: Relationships between Distributive and Regulatory Politics," Yearbook of Politics and Public Policy, in press, 1974.
- #2 Perkins, Priscilla C., "Interdisciplinary Study of Lake Powell, USA: Consequences of Water Management Decisions in an Arid Region," Proceedings of the First World Congress on Water Resources, International Water Resources Association, in press, 1974.
- #3 Hansmann, Eugene W., David E. Kidd, and E. Gilbert, "Man's Impact on a Newly Formed Reservoir," Hydrobiologia, in press, 1974.
- #4 Kunitz, Stephen J., "Factors Influencing Recent Navajo and Hopi Population Change," Human Organization, in press, 1974.
- #5 Standiford, Donald, Loren Potter, and David Kidd, "Mercury Levels in Lake Powell," submitted to Environmental Science and Technology.
- #6 Kidd, David E., and Eugene W. Hansmann, "Further Evidence of Man's Impact on a Newly Formed Reservoir," submitted to Environmental Pollution.
- #7 Kunitz, Stephen J., "Hopi and Navajo Fertility, 1971-1972," Human Biology, in press, 1974.
- #8 Price, Monroe E., and Reid Peyton Chambers, "Regulation of Leasing and Economic Development on Indian Reservations," submitted to Stanford Law Review.
- #9 Jacoby, Gordon C., Jr., "Lake Powell Research Project: Hydrologic Research," Hydrology and Water Resources in Arizona and the Southwest, Vol. 3, in press, 1973.
- #10 Reynolds, Robert C., Jr., "Chemistry of Lake Powell," Hydrology and Water Resources in Arizona and the Southwest, Vol. 3, in press, 1973.

2. Research Calendar. This section presents the target dates for the completion of data gathering, analysis, and writing tasks by subproject.

a. Biological Limnology, Subproject No. 1

1. Data Collection--2 months at a time during the summers of 1974 and 1975; 2 weeks at a time during the months of October, January, and March of each funding year.

Completed: March 1976

2. Data Analysis--ongoing

Completed: May 1976

3. Reporting Results--major time devoted to this task will be during the winter months of both years.

Completed: May 1976

b. Shoreline Ecology, Subproject No. 2

1. Data Collection--fieldwork; monthly trips to the lake plus full-time work on lake during summers.

Completed: May 1976

2. Data Analysis--cartographic work, laboratory analysis, and data reduction.

Completed: 1 June 1976

3. Reporting Results

Completed: 1 June 1976

c. Heavy Metals, Subproject No. 3

1974. 1. Data Collection--March, July, and November

Completed: 1 December 1974

2. Data Analysis

Completed: May 1975

3. Reporting Results

Completed: 1 June 1975

d. Hydrology, Subproject No. 4

1. Data Collection

Completed: 30 December 1974

2. Data Analysis

Completed: 30 December 1975

3. Reporting Results

Completed: 30 May 1976

- e. Sedimentation, Subproject No. 5
 - 1. Data Collection Completed: December 1974
 - 2. Data Analysis Completed: December 1975
 - 3. Reporting Results Completed: 30 May 1976
- f. Lake Geochemistry, Subproject No. 6
 - 1. Data Collection Completed: December 1974
 - 2. Data Analysis Completed: December 1975
 - 3. Reporting Results Completed: 30 May 1976
- g. Physical Limnology, Subproject No. 7
 - 1. Data Collection Completed: December 1974
 - 2. Data Analysis Completed: December 1975
 - 3. Reporting Results Completed: 30 May 1976
- h. Air Quality, Subproject No. 8
 - 1. Data Collection Completed: 30 November 1974
 - 2. Data Analysis Completed: 31 May 1975
 - 3. Reporting Results Completed: 31 May 1976
- i. Plume Analysis, Subproject No. 9
 - 1. Data Collection Completed: January 1976
 - 2. Data Analysis Completed: February 1976
 - 3. Reporting Results Completed: May 1976
- j. Kaiparowits Resources, Subproject No. 10
 - 1. Data Collection--literature search, October, 1974; bibliography, November 1974; fieldwork, December 1975.
Completed: December 1975

2. Data Analysis

Completed: January 1976

3. Reporting Results--bibliography, October 1975; "data book," January 1976; Bulletins, May 1976; final report, April 1976.

Completed: April 1976

k. Political Science I, Subproject No. 111. Data Collection

Completed: March 1975

2. Data Analysis

Completed: 30 December 1975

3. Reporting Results

Completed: March 1976

l. Political Science II, Subproject No. 121. Data Collection

Completed: 1 June 1975

2. Data Analysis

Completed: 1 November 1975

3. Reporting Results

Completed: 30 March 1976

m. Law, Subproject No. 131. Data Collection

Completed: 31 August 1975

2. Data Analysis

Completed: 31 January 1976

3. Reporting Results

Completed: 31 May 1976

n. Epidemiology, Subproject No. 14

1. Data Collection--Navajo demography, September 1974; Utah demography, December 1974; health report monitoring, December 1975.

Completed: December 1975

2. Data Analysis

Completed: 1 January 1976

3. Reporting Results

Completed: 31 May 1976

o. Anthropology, Subproject No. 15

1. Data Collection--political interviews, December 1974; document collection, 1 January 1976.

Completed: January 1976

2. Data Analysis--local socioeconomic, December 1974; political attitudes, December 1975; reservation-wide economic, January 1976.

- Completed: 30 January 1976
 3. Reporting Results
 Completed: May 1976

p. Sociology, Subproject No. 16

1. Data Collection Completed: October 1974
 2. Data Analysis Completed: November 1975
 3. Reporting Results Completed: 1 June 1976

q. Economics, Subproject No. 17

1. Data Collection Completed: September 1975
 2. Data Analysis--regional study, August 1975; recreational carrying capacity, September 1976; area analysis, September 1976.
 Completed: May 1976
 3. Reporting Results Completed: September 1976

C. Budget Summaries

1. Comparison between Direct Costs for 1972-1974 and Those Proposed for 1974-1976. On November 2, 1973, the Steering Committee set a limit of the total budgets of all subprojects. It was decided to limit the total Direct Costs to the sum of \$1,082,000. This sum was the same as the Direct Costs of the total Project's budget in the 1972-1974 period. By taking this action, the Project assumed all inflation rises found in direct charges, such as those in salaries, wages, supplies, and services, and in turn proposed that the National Science Foundation assume the inflationary increases arising in the Indirect Costs.

During the last half of 1973, the Project eliminated subprojects in impact analysis and systems analysis, and consolidated three subprojects in various fields of hydrology into one subproject in hydrology. The Steering Committee approved a new project in political science and an expanded project in economics. The Air Quality Subproject was split, yielding plume analysis in addition to air quality. A subproject was added concerning

NOTE: As of April 12, 1974, the budgets of subprojects 1, 3, 4, and 11 were changed in response to recommendations of the NSF Program Manager to the LPRP.(See Table 5 for details.)

revised April 12, 1974

the resources of the Kaiparowits Plateau. The comparison between the Direct Costs budgets of 1972-1974, those submitted January 21, 1974, and those of the April 12 and 15, 1974, revisions is shown in Table 5.

2. Summaries of Subproject Budgets. The detailed breakdown of the individual subproject budgets as of the April 12 and 15, 1974, revisions is presented in Part D of this proposal.

3. Budget Breakdown by Institution. The institutional budget breakdown, as of April 15, 1974 (reflecting LPRP response to recommendations of the NSF Program Manager and reviewers), is presented below.

	<u>Direct Costs</u> (2 Years)	<u>Total Costs</u> (2 Years)
<u>University of New Mexico, Biology Department</u>		
Biological Limnology, Shoreline Ecology, and Heavy Metals	\$222,730	\$279,112
<u>Dartmouth College, Department of Earth Sciences</u>		
Sedimentation, Lake Geochemistry, and Physical Limnology	\$129,626	\$161,138
<u>UCLA, Institute of Geophysics and Planetary Physics</u>		
Hydrology, Kaiparowits Resources, and Natural Sciences Coordinator	\$238,077	\$281,205
<u>UCLA, School of Law</u>		
Law	\$ 44,000	\$ 51,366
<u>UCSB, Department of Political Science</u>		
Political Science I	\$ 31,394	\$ 42,332
<u>University of Arizona, Department of Anthropology</u>		
Anthropology and Social Sciences Coordinator	\$151,244	\$186,539

revised April 12, 1974
re-revised April 15, 1974

	<u>Direct Costs</u> (2 Years)	<u>Total Costs</u> (2 Years)
<u>University of Arizona, Institute of Government Research</u>		
Political Science II	\$ 27,495	\$ 35,396
<u>Arizona State University, Sociology Department</u>		
Sociology	\$ 54,718	\$ 74,358
<u>University of Rochester, School of Medicine and Dentistry</u>		
Epidemiology	\$ 17,850	\$ 21,472
<u>Northern Arizona Society of Science and Art, Inc.</u>		
Air Quality	\$ 38,000	\$ 55,100
<u>John Muir Institute</u>		
Economics and Plume Analysis	<u>\$145,188</u>	<u>\$195,873</u>
TOTAL:	\$1,100,322	\$1,383,891

Table 5

COMPARISON OF TOTAL DIRECT COSTS BETWEEN OLD AND NEW FUNDING PERIODS

1972-1974 Funding	Proposal for 1974-1976 as submitted January 21, 1974	Proposal for 1974-1976 as revised April 12, 1974	Proposal for 1974-1976 as re-revised April 15, 1974
Biological Limnology	140,621	(4) 130,788	SAME
Shoreline Ecology	40,977	SAME	
Heavy Metals	38,873	(3) 43,470	SAME
Streamflow Trends	39,303	(3) 86,989	94,339
Lake Evaporation	49,288	SAME	SAME
Bank Storage	42,931	SAME	SAME
Physical Limnology	52,960	SAME	SAME
Lake Geochemistry	54,626	SAME	(2) 49,248
Sedimentation	45,594	SAME	SAME
Background Air Quality	77,730	SAME	SAME
Impact Analysis	40,893	31,394	SAME
		27,495 (NEW)	SAME
		0	

Table 5
(Continued)

1972-1974 Funding	Proposal for 1974-1976 as submitted January 21, 1974	Proposal for 1974-1976 as revised April 12, 1974	Proposal for 1974-1976 as re-revised April 15, 1974
Law and Political Science	68,557	Law	SAME
Epidemiology	24,194	Epidemiology	SAME
Anthropology	116,587	Anthropology	SAME
Economics	59,080	Economics	SAME
Systems Analysis	62,958	Sociology	SAME
Coordinator Social Sciences	23,140	Coordinator Social Sciences	SAME
Coordinator Natural Sciences	104,252	Coordinator Natural Sciences	SAME
TOTAL:	1,082,164	1,082,000	1,100,322

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revised April 12, 1974
re-revised April 15, 1974

(1) The Political Science Subproject submitted January 21, 1974, was split (in the revision of April 12, 1974) into two separate subprojects (Political Science I and Political Science II) in response to NSF recommendations to the LPRP.

(2) Reflects a \$1,200 mathematical error in 1974-1976 Lake Geochemistry Subproject proposal travel budget and correction of same.

(3) Reflects an increase due to reviewers' comments and LPRP response.

(4) Reflects a decrease due to reviewers' comments and LPRP response.